US005725044A

United States Patent [19]

Hirokawa

[11] Patent Number: 5,725,044

[45] Date of Patent: Mar. 10, 1998

[54] CASTING METHOD USING A FORMING DIE

[76] Inventor: Koji Hirokawa, 1053, Ota-Machi, Isesaki-shi, Gunma-ken, Japan

[21] Appl. No.: 519,170

[22] Filed: Aug. 25, 1995

[30] Foreign Application Priority Data

Aug. 30, 1994	[JP]	Japan	6-205543
Sep. 26, 1994	[JP]	Japan	6-229962
Oct. 4, 1994	[JP]	Japan	6-240352
Mar. 20, 1995	[JP]	Japan	7-060967
Mar. 29, 1995	[JP]	Japan	7-071645
Apr. 18, 1995	[JP]	Japan	7-092807

[51] Int. Cl.[6] B22D 29/00; B22C 1/00

[52] U.S. Cl. 164/131; 164/132; 164/138

[58] Field of Search 164/131, 132, 164/369, 120, 138

[56] References Cited

U.S. PATENT DOCUMENTS

2,454,819	11/1948	Leipzig .	
4,573,519	3/1986	Donomoto et al.	164/131
4,691,756	9/1987	Suzuki et al.	164/361
4,712,600	12/1987	Hamajima et al.	164/97
5,303,761	4/1994	Flessner et al.	164/15
5,318,091	6/1994	Pavoni et al. .	
5,355,933	10/1994	Voss	164/132
5,566,742	10/1996	Nemoto	164/132

FOREIGN PATENT DOCUMENTS

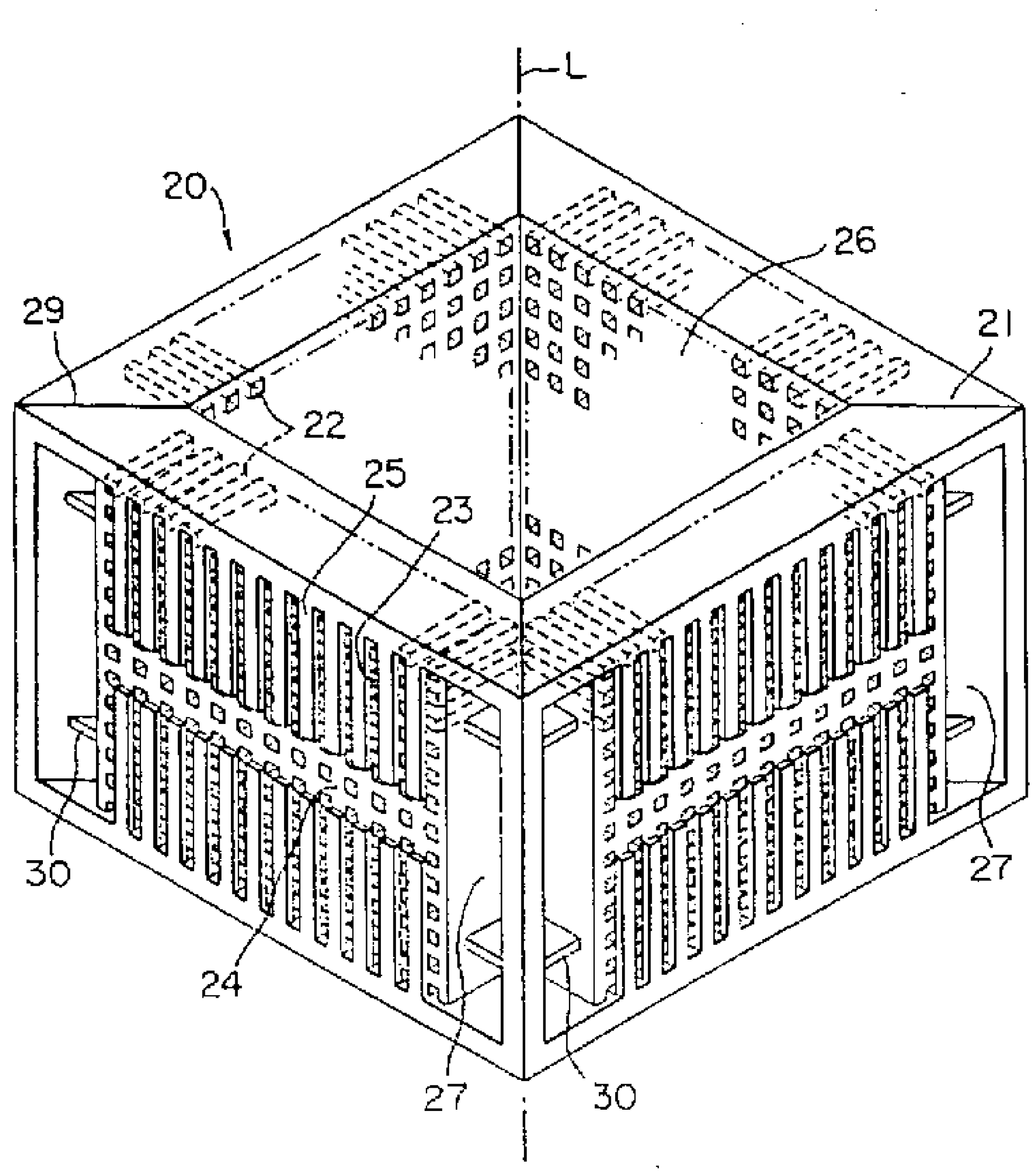
0006721	1/1980	European Pat. Off. .	
0166228	1/1986	European Pat. Off. .	
0257425	3/1988	European Pat. Off. .	
0309378	3/1989	European Pat. Off. .	
0347627	12/1989	European Pat. Off. .	
2332055	1/1974	Germany .	
2843688	10/1979	Germany .	
4325562	5/1994	Germany	164/369
54-60220	5/1979	Japan	164/132
61-293646	12/1986	Japan	164/132
5-192762	8/1993	Japan	164/131
6-87052	3/1994	Japan .	
6-87063	3/1994	Japan .	
6-87064	3/1994	Japan .	
6-91345	4/1994	Japan .	
6-91346	4/1994	Japan .	
6-91565	4/1994	Japan .	
6-99247	4/1994	Japan .	
6-99436	4/1994	Japan .	
6-122037	5/1994	Japan .	
6-126376	5/1994	Japan .	
6-198388	7/1994	Japan .	
0629291A	10/1994	Japan .	
06328195A	11/1994	Japan .	
07001079A	1/1995	Japan .	
07001080A	1/1995	Japan .	
07003997A	1/1995	Japan .	
5597706	6/1977	U.S.S.R.	164/132
1199673	7/1970	United Kingdom .	
1574634	9/1980	United Kingdom .	
2156720	10/1985	United Kingdom .	
2269771	2/1994	United Kingdom	164/132
WO89/09106	10/1989	WIPO .	

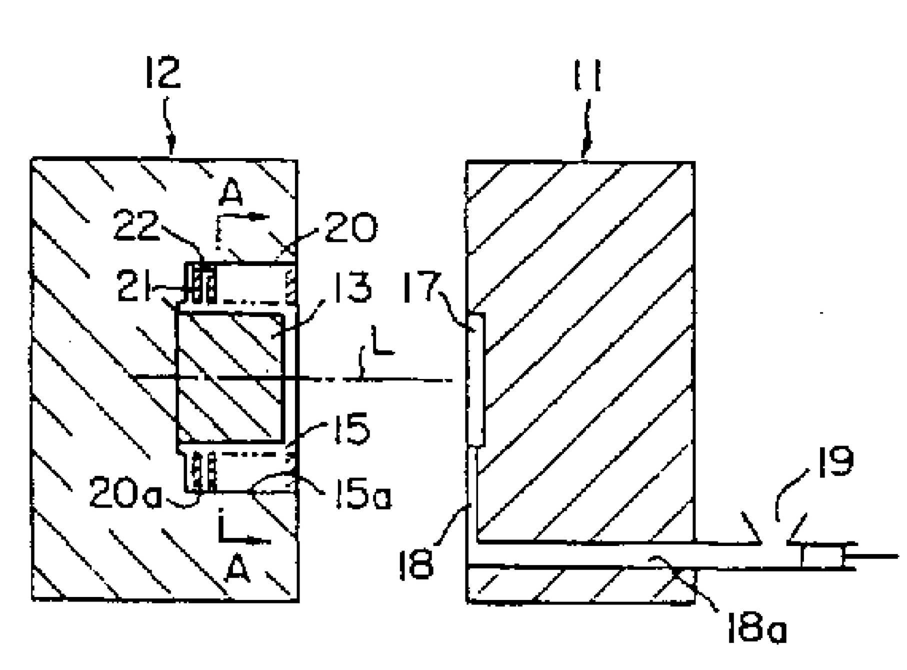
Primary Examiner—Joseph J. Hail, III
Assistant Examiner—I.-H. Lin
Attorney, Agent, or Firm—Jacobson, Price, Holman & Stern, PLLC

[57] ABSTRACT

A plastic forming die for formation of outer surface is set on the inner surface of a cavity of a die. The forming die has a forming die body in a square barrel shape, and there are a lot of through holes provided between mount surfaces and inner side surfaces of the forming die body. Grooves communicating with the through holes are provided in the mount surfaces. When a molten metal is injected into the cavity, the through holes of the forming die body form outwardly projecting portions of a cast product. The forming die is then melted to be removed from the cast product.

24 Claims, 39 Drawing Sheets





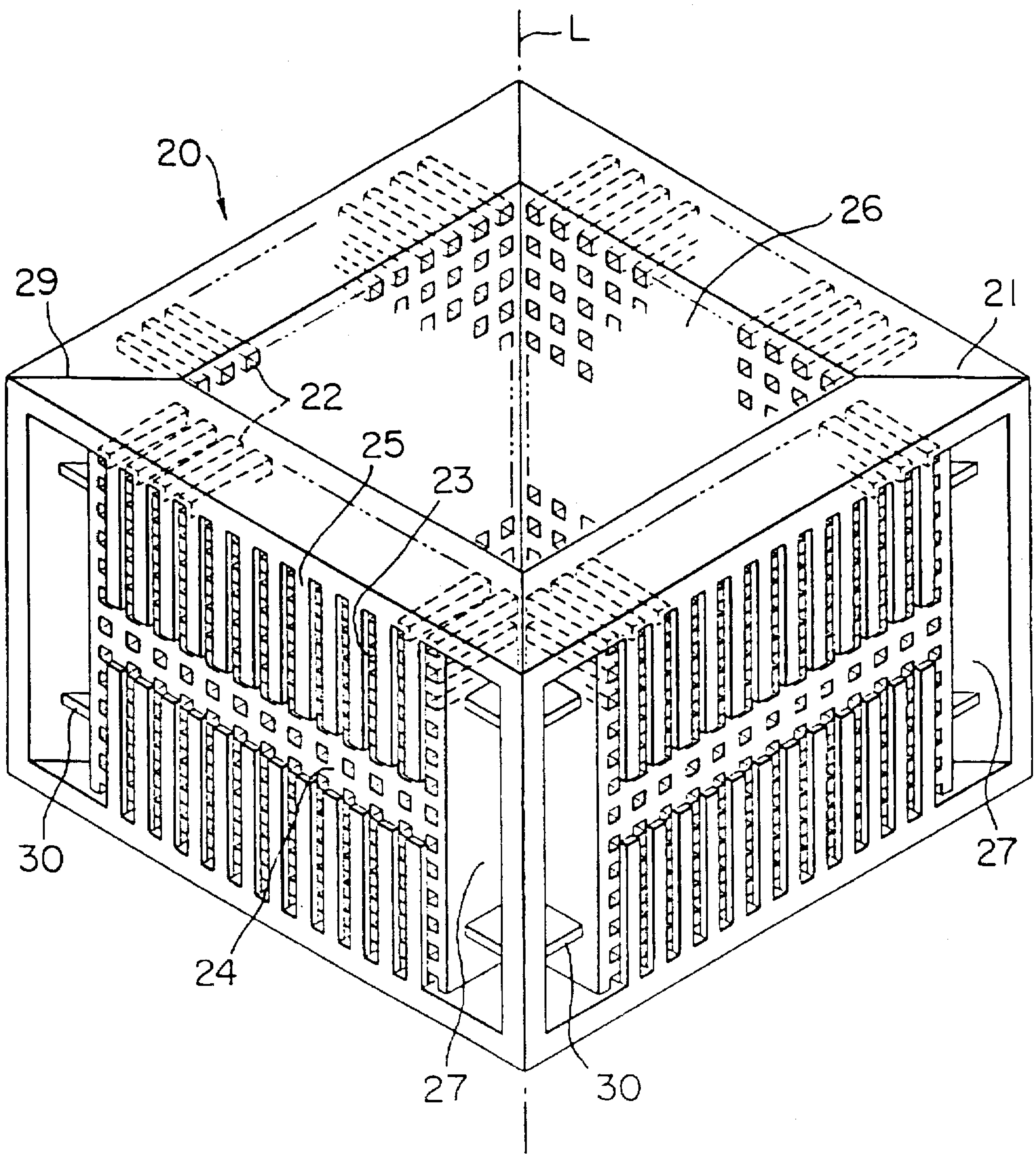


FIG. 1

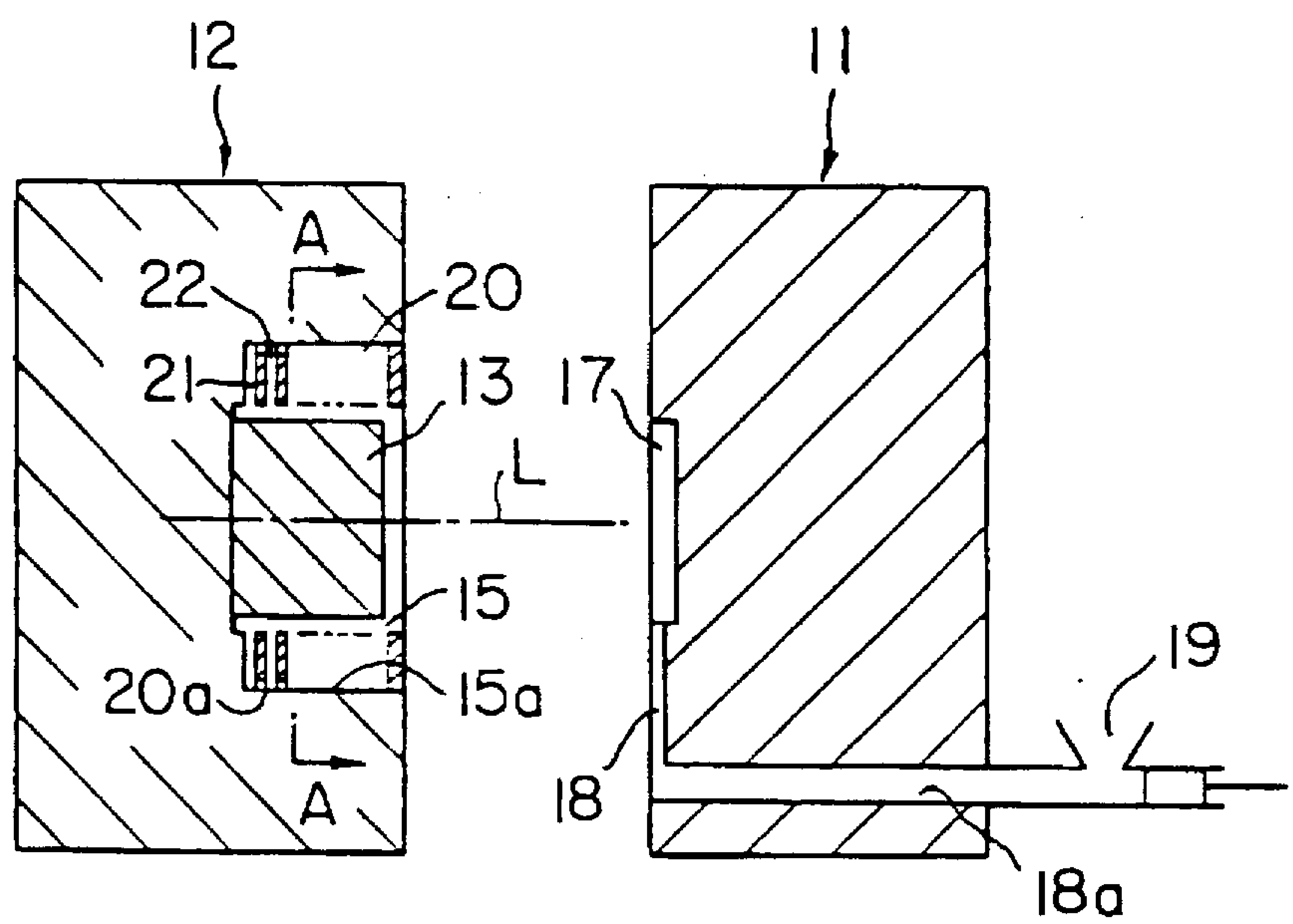


FIG. 2

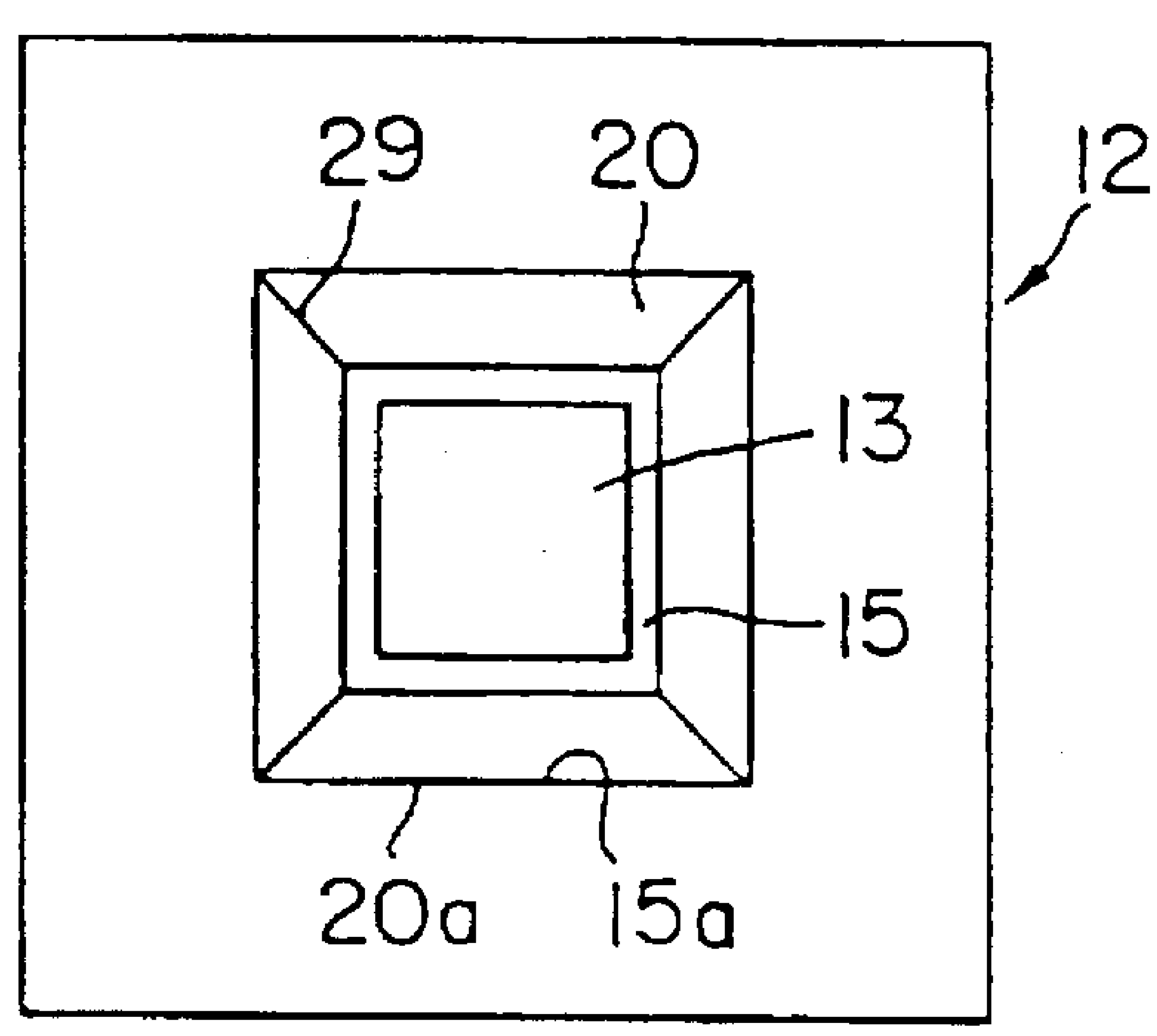


FIG. 3A

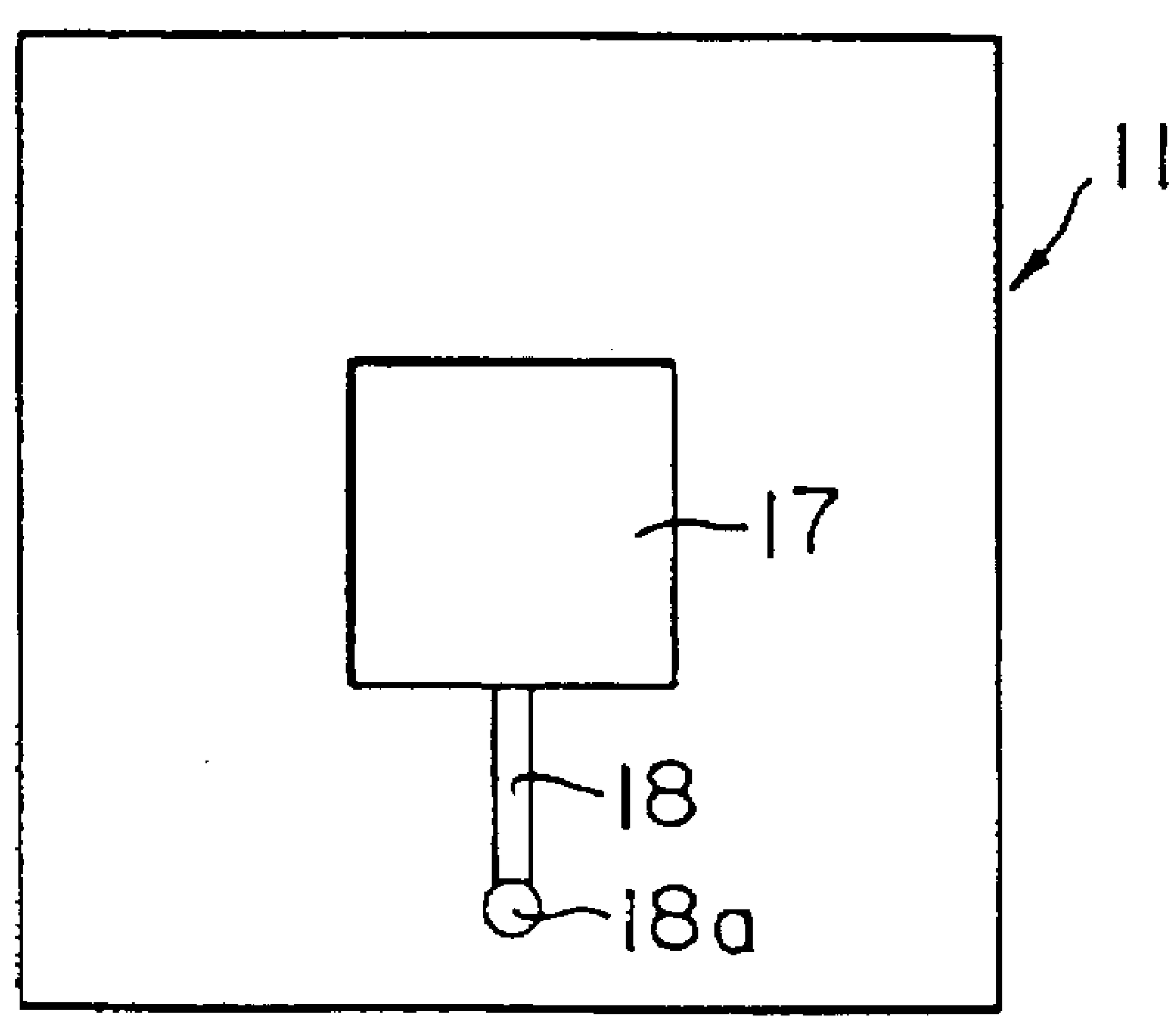


FIG. 3B

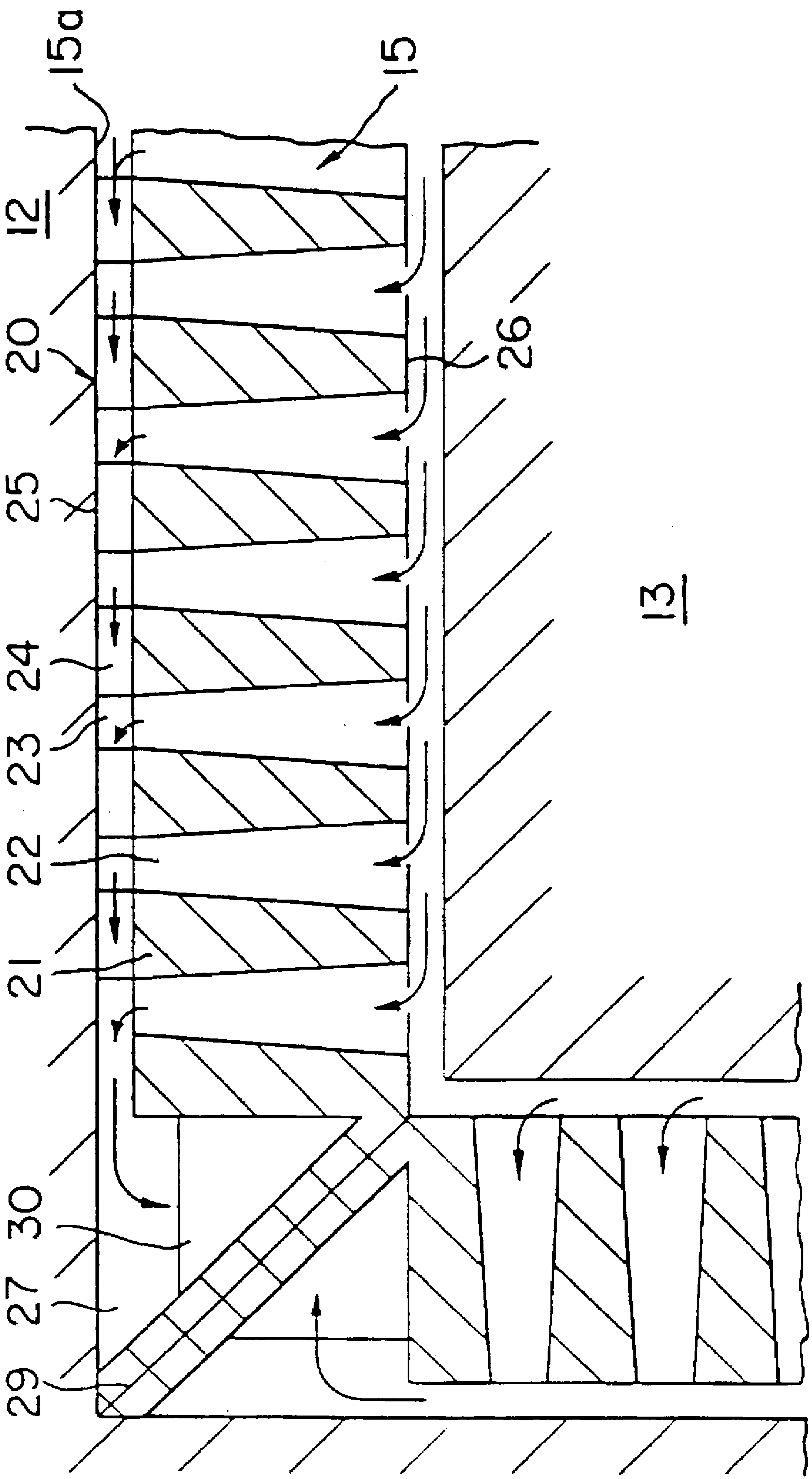


FIG. 4

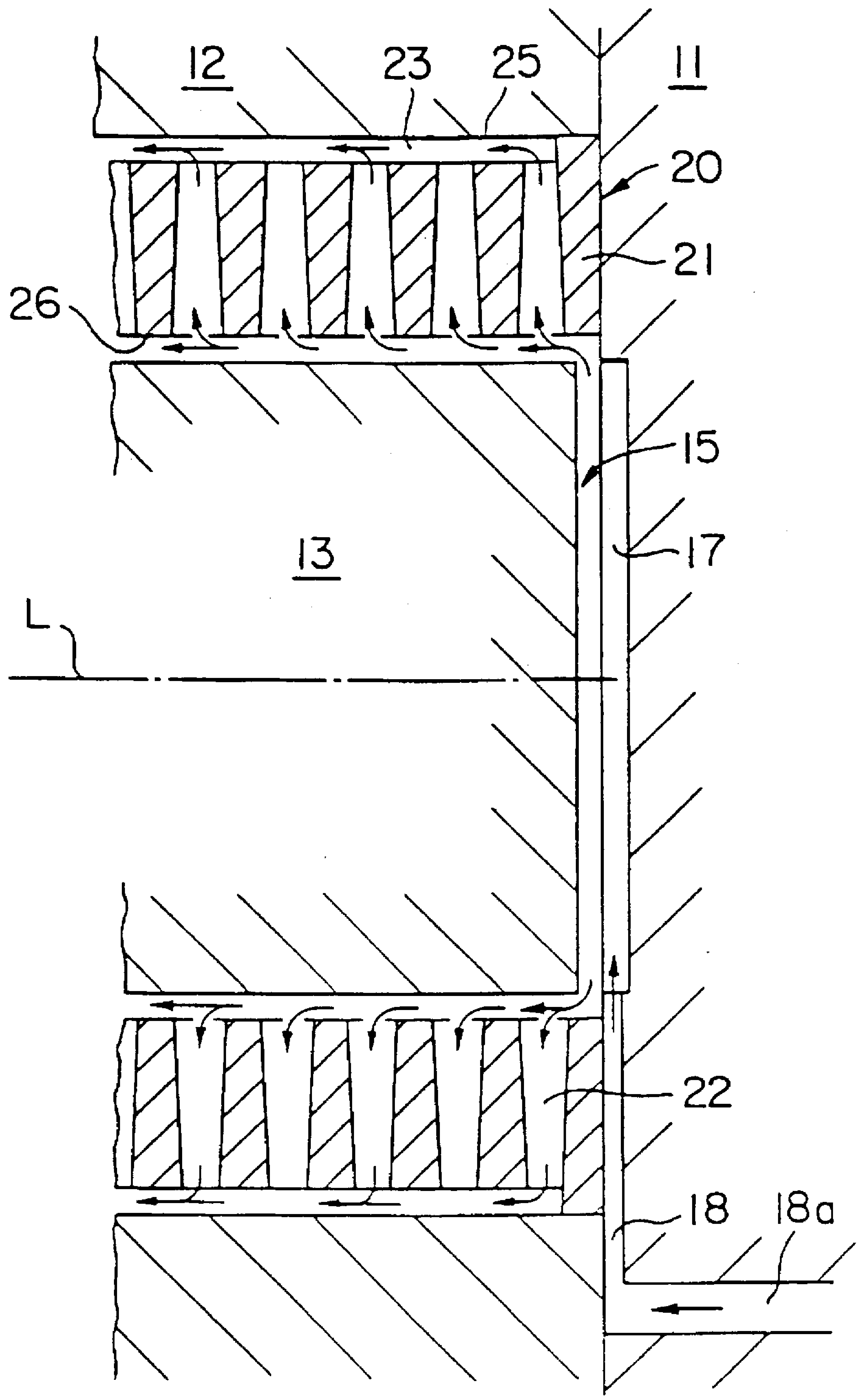


FIG. 5

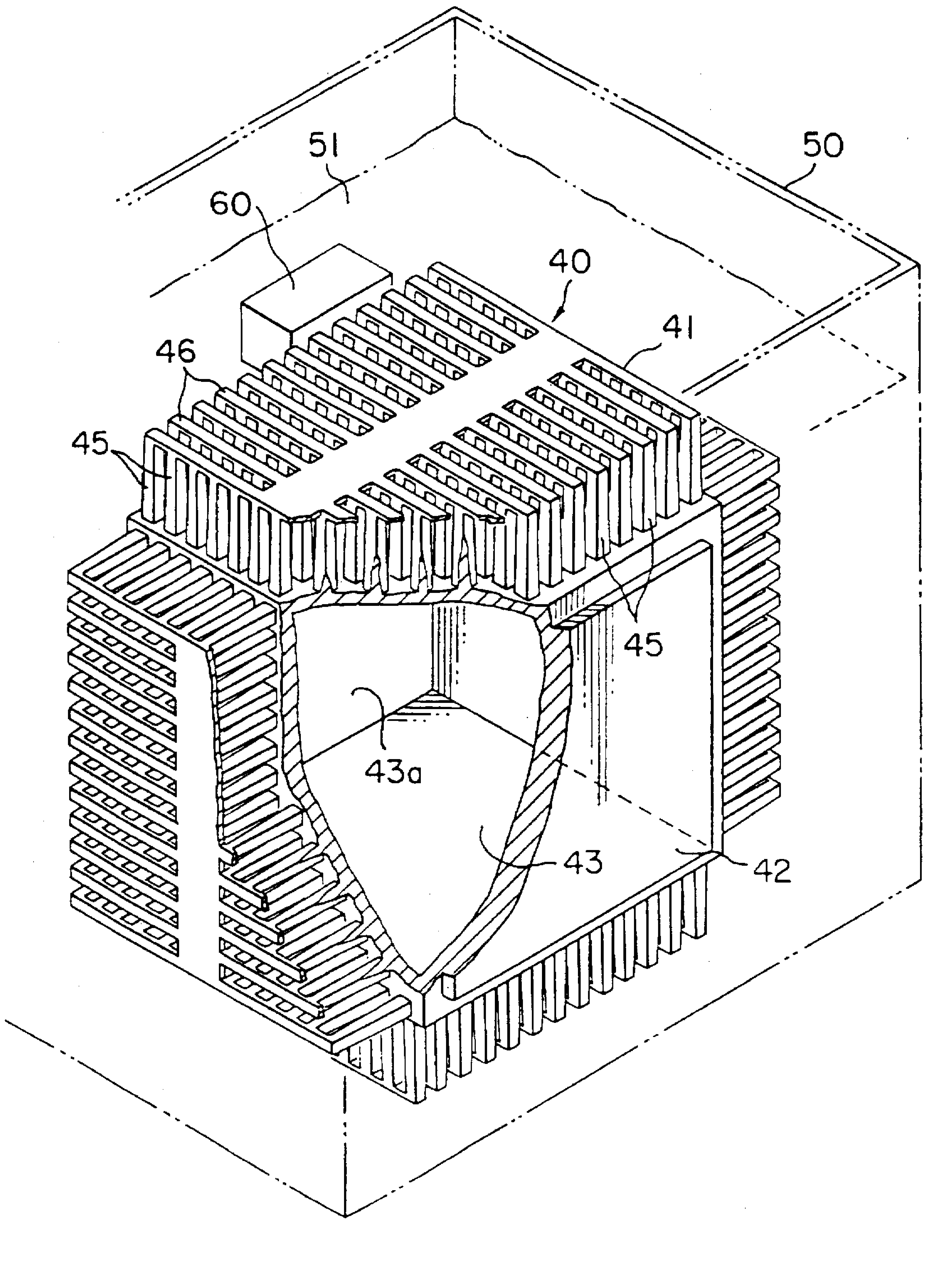


FIG. 6

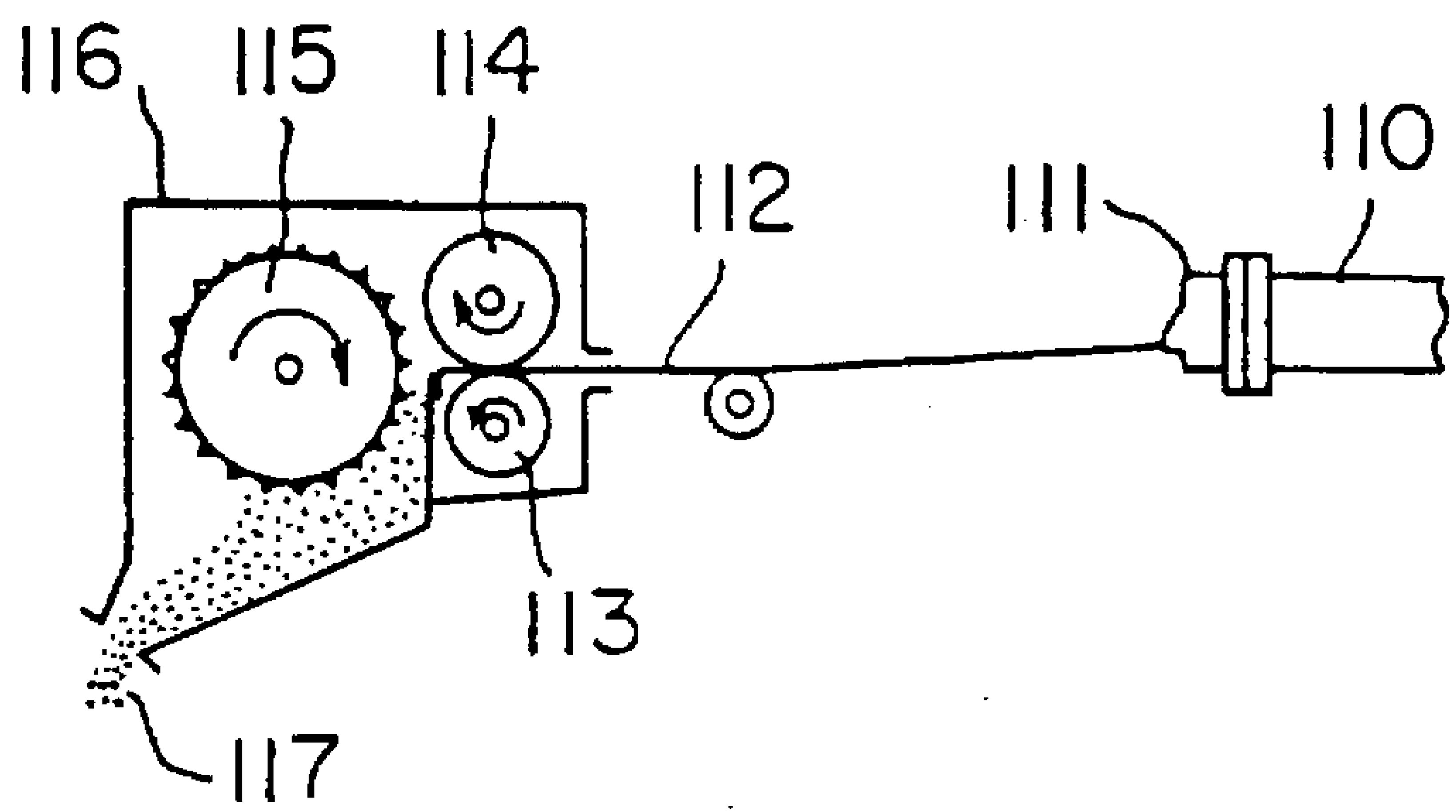

116
115
114
110
112
111
113
117

FIG. 7

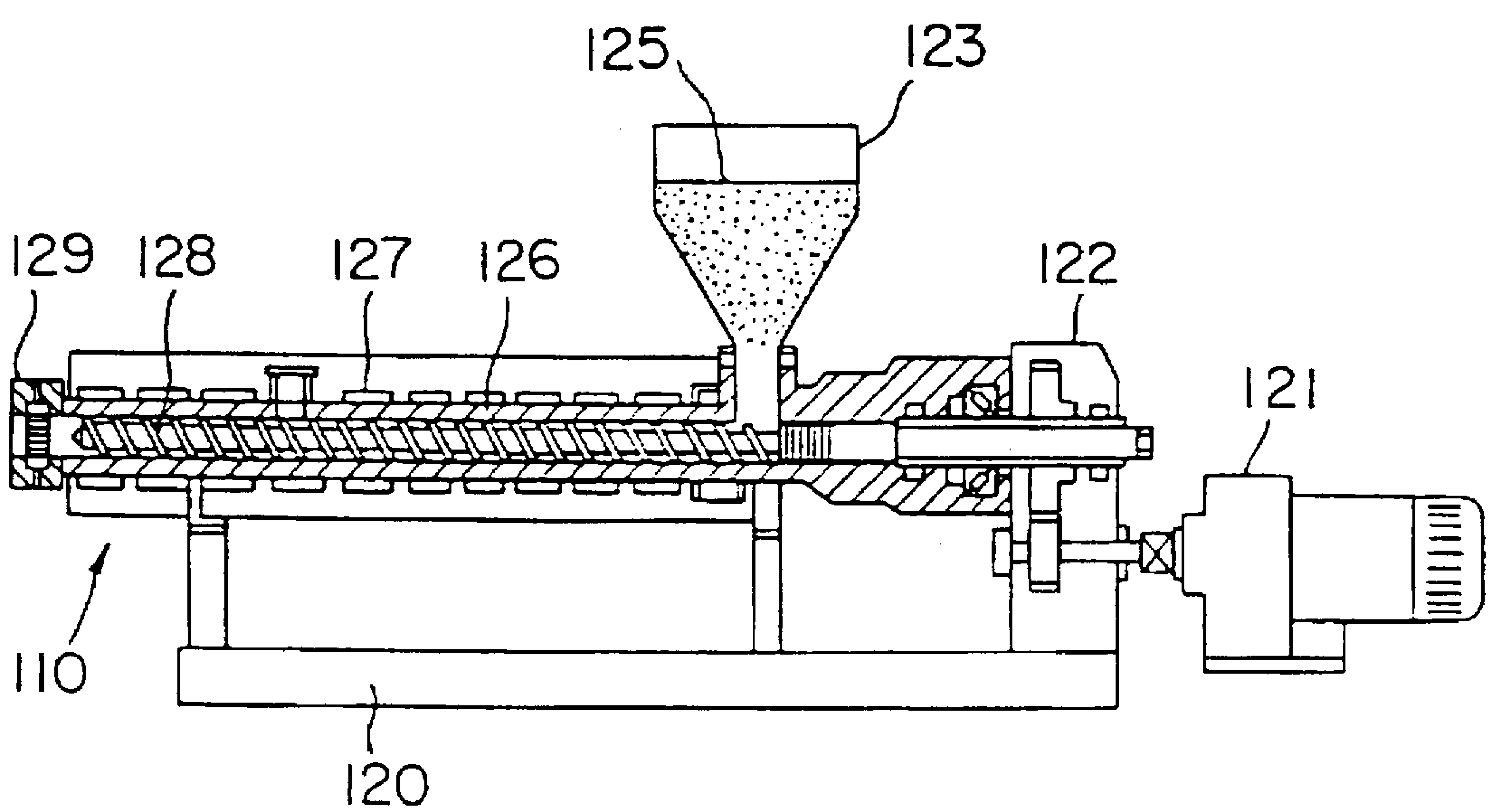

125
123
129
128
127
126
122
121
110
120

FIG. 8

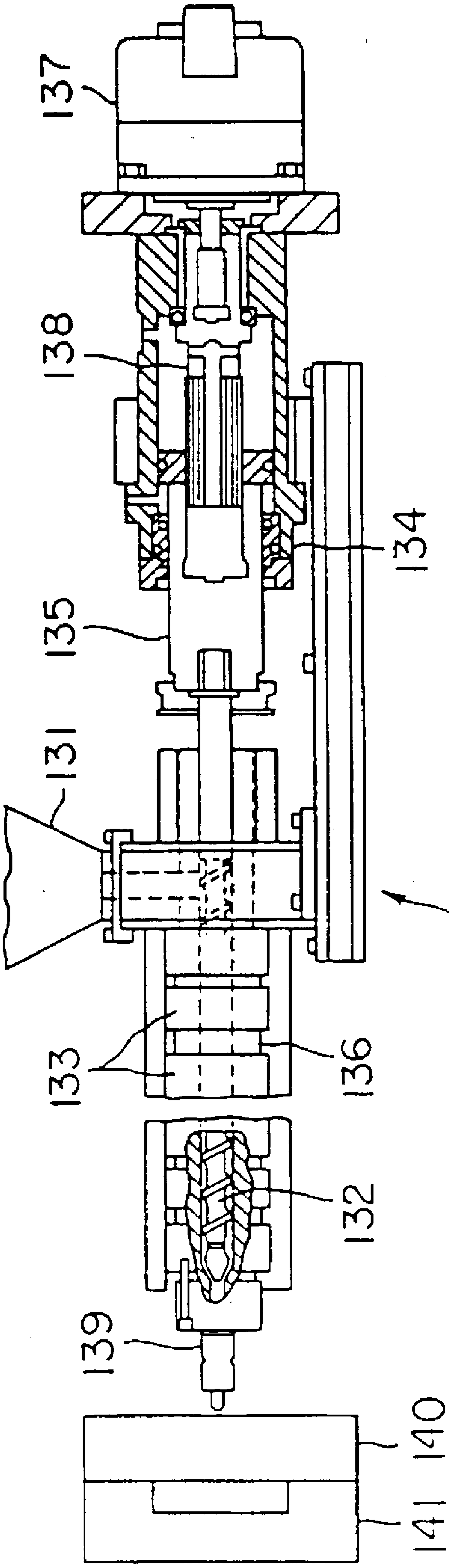
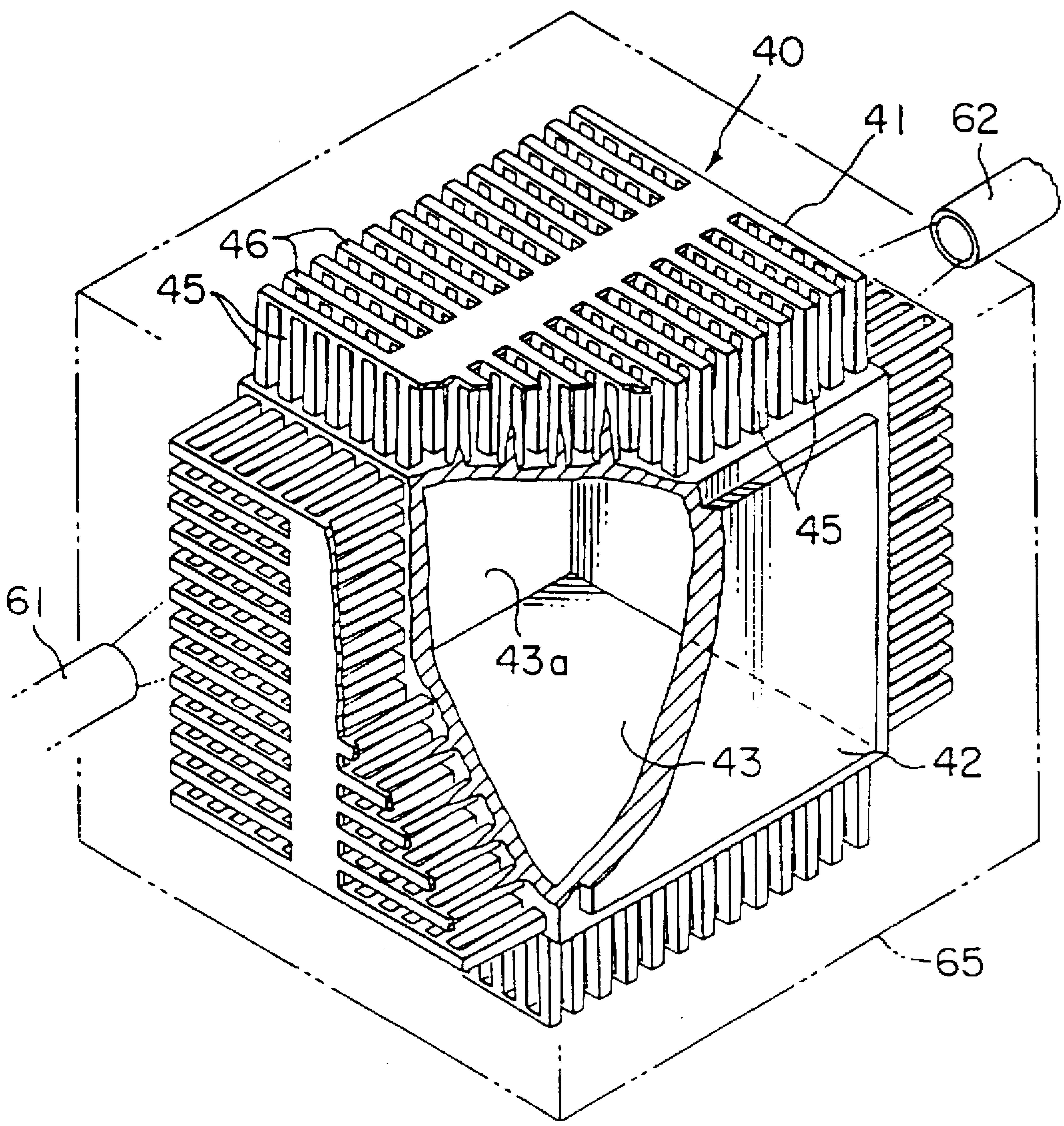
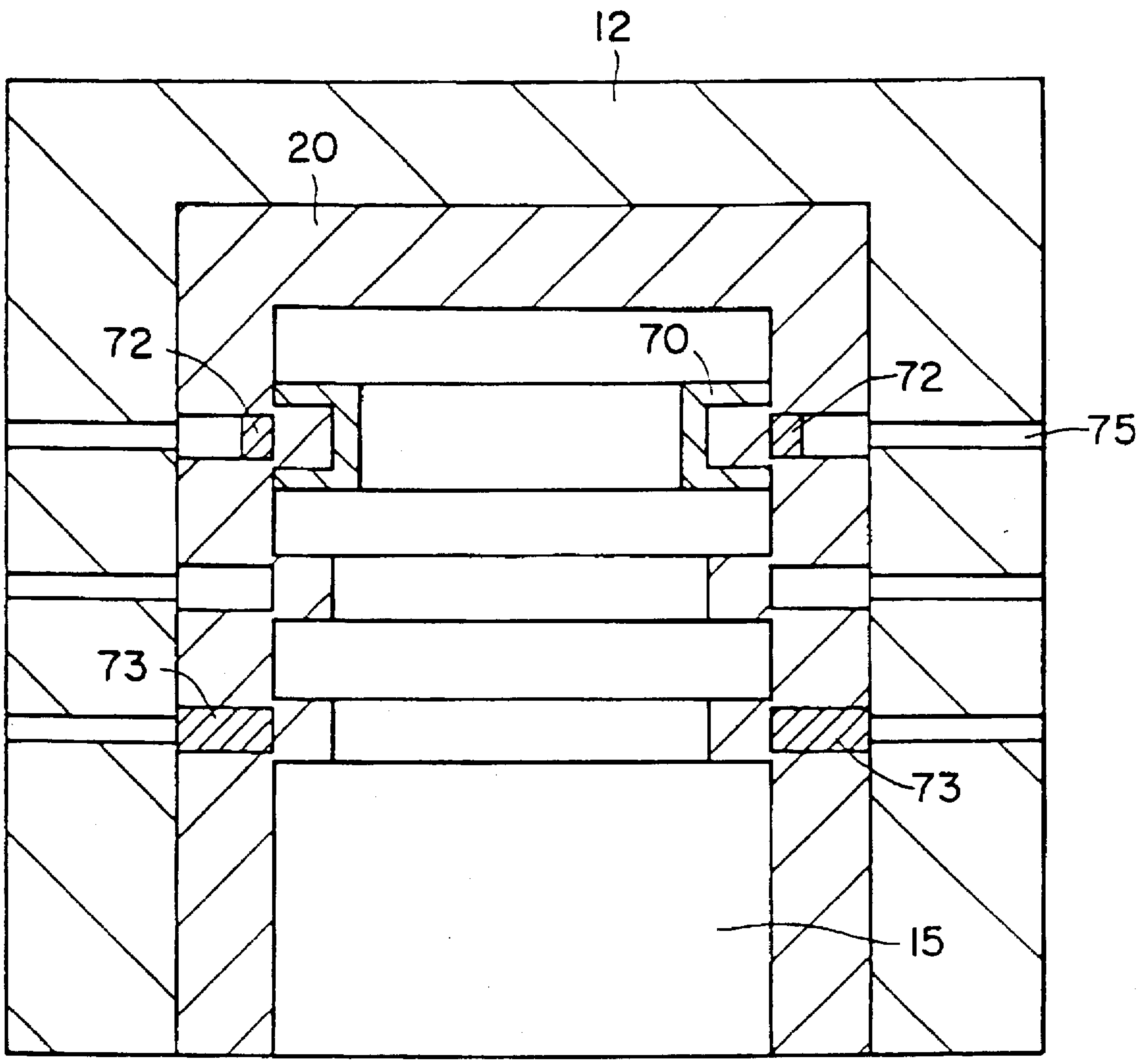


FIG. 9



F I G. 10



F I G. 11

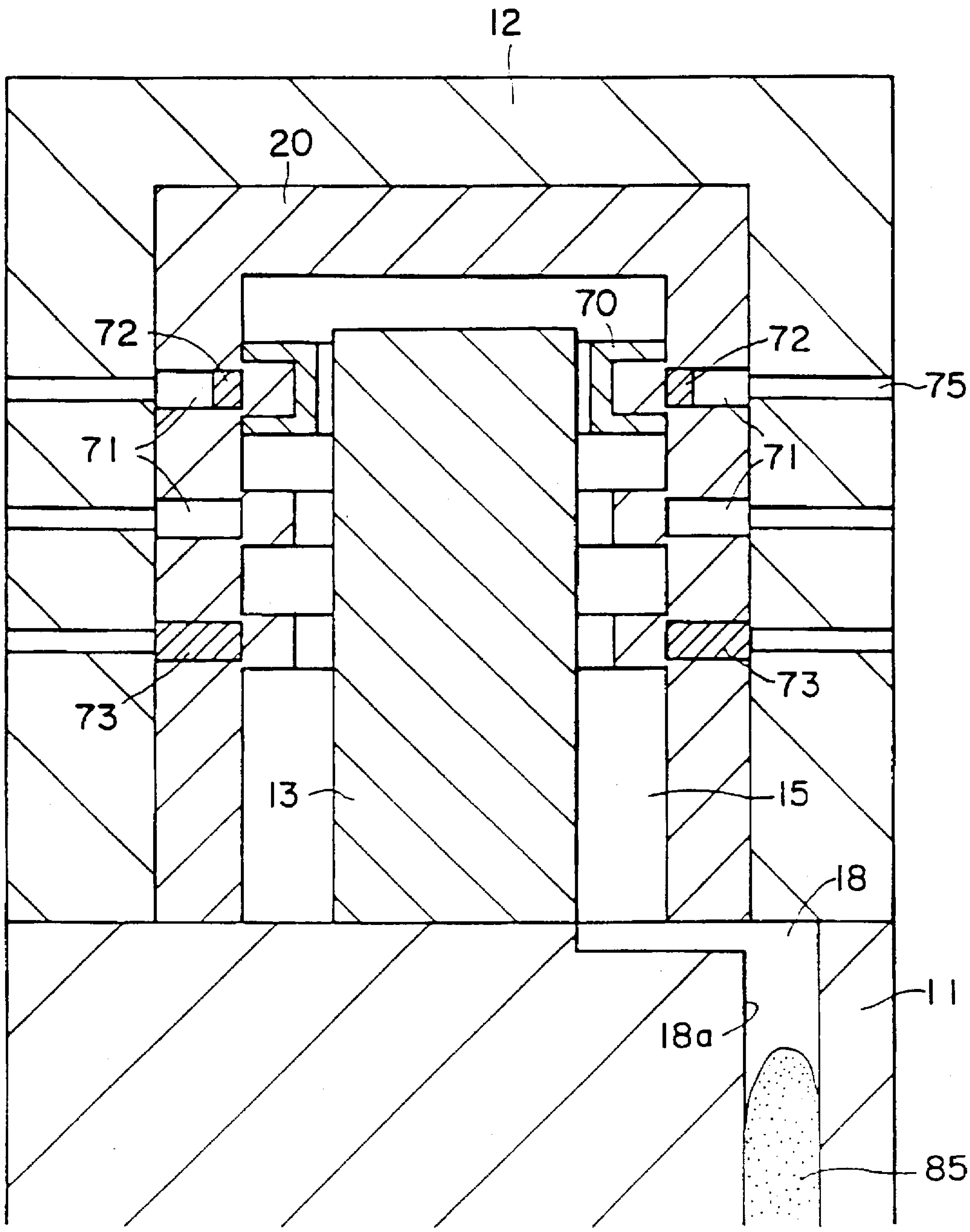


FIG. 12

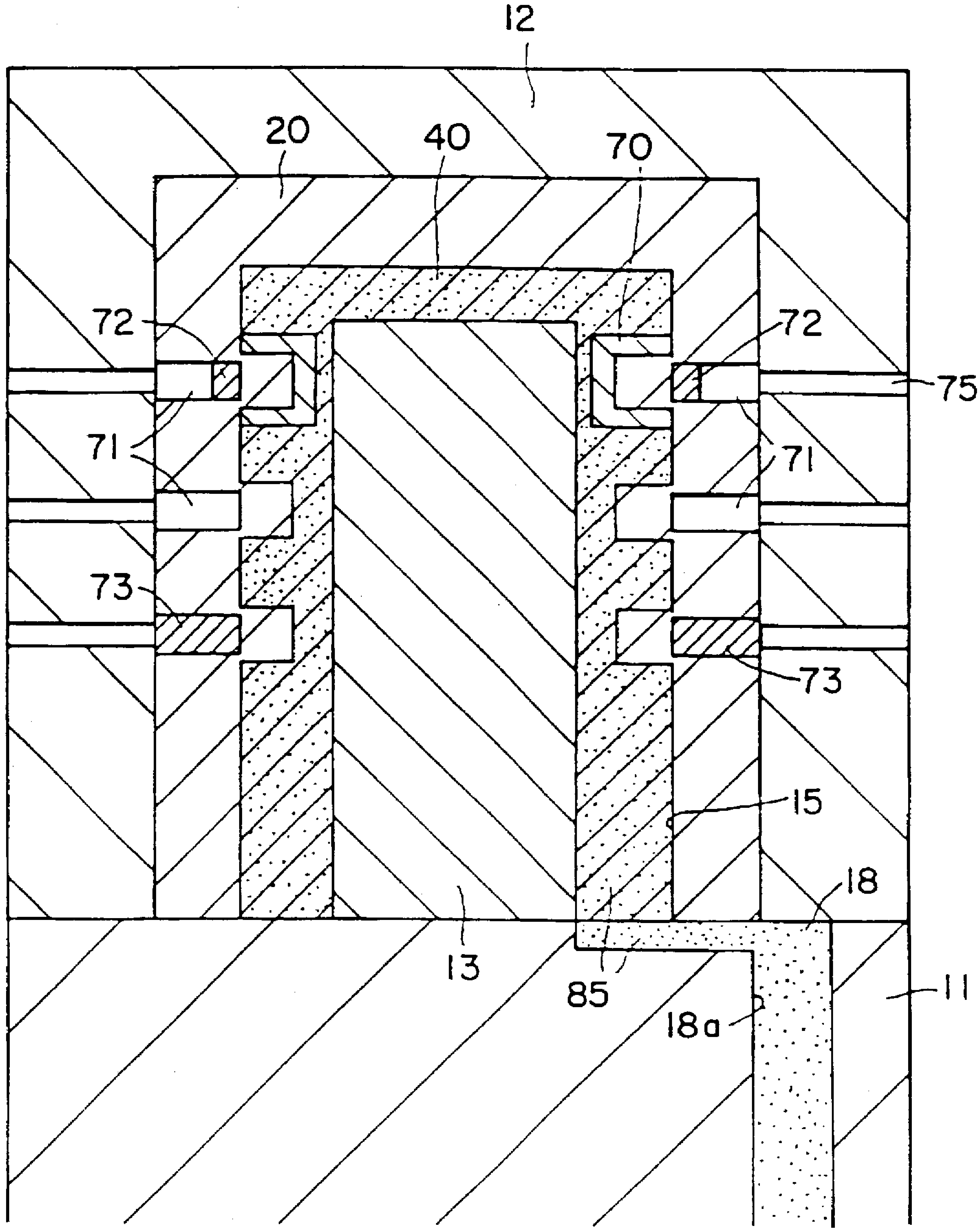


FIG. 13

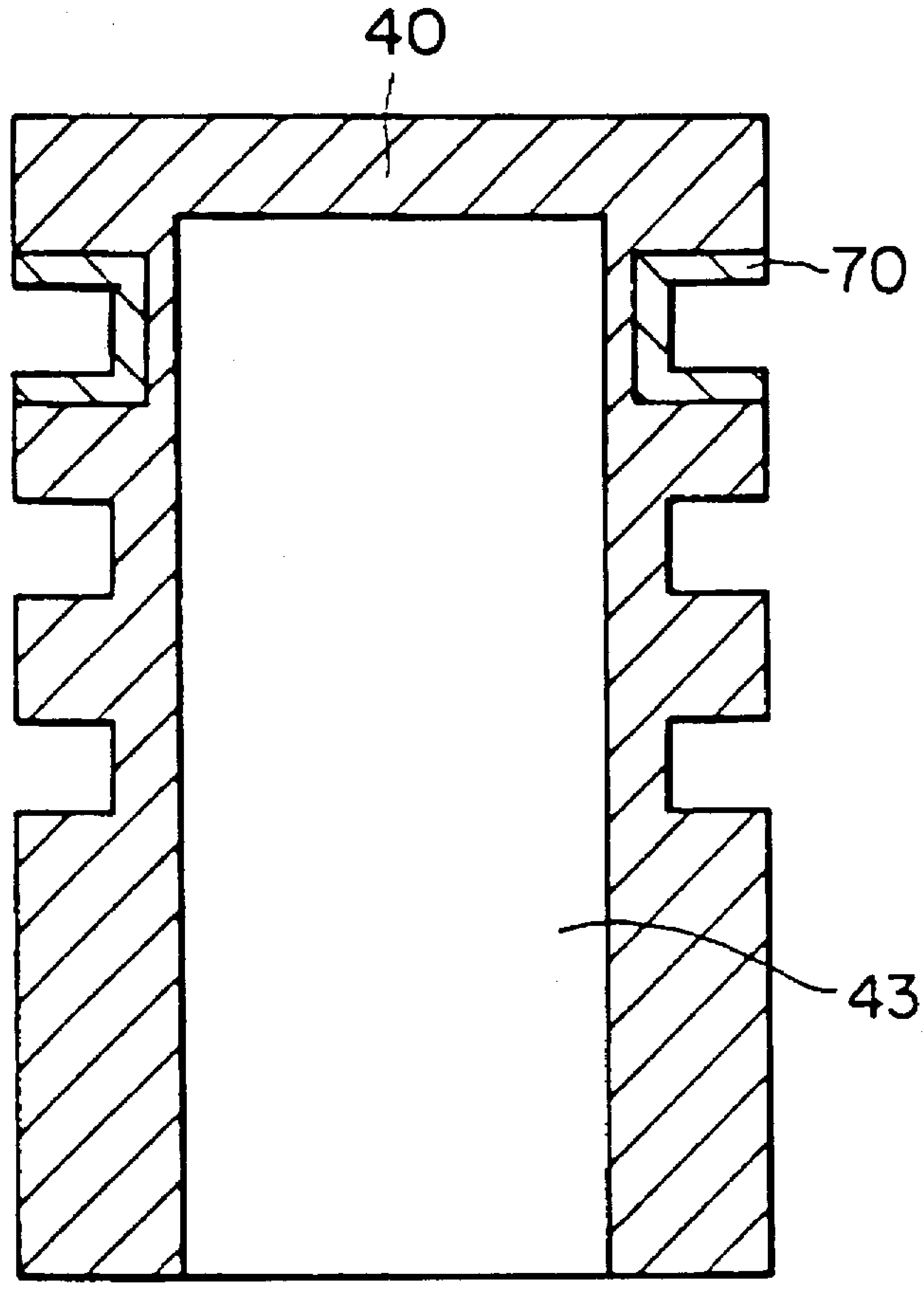


FIG. 14

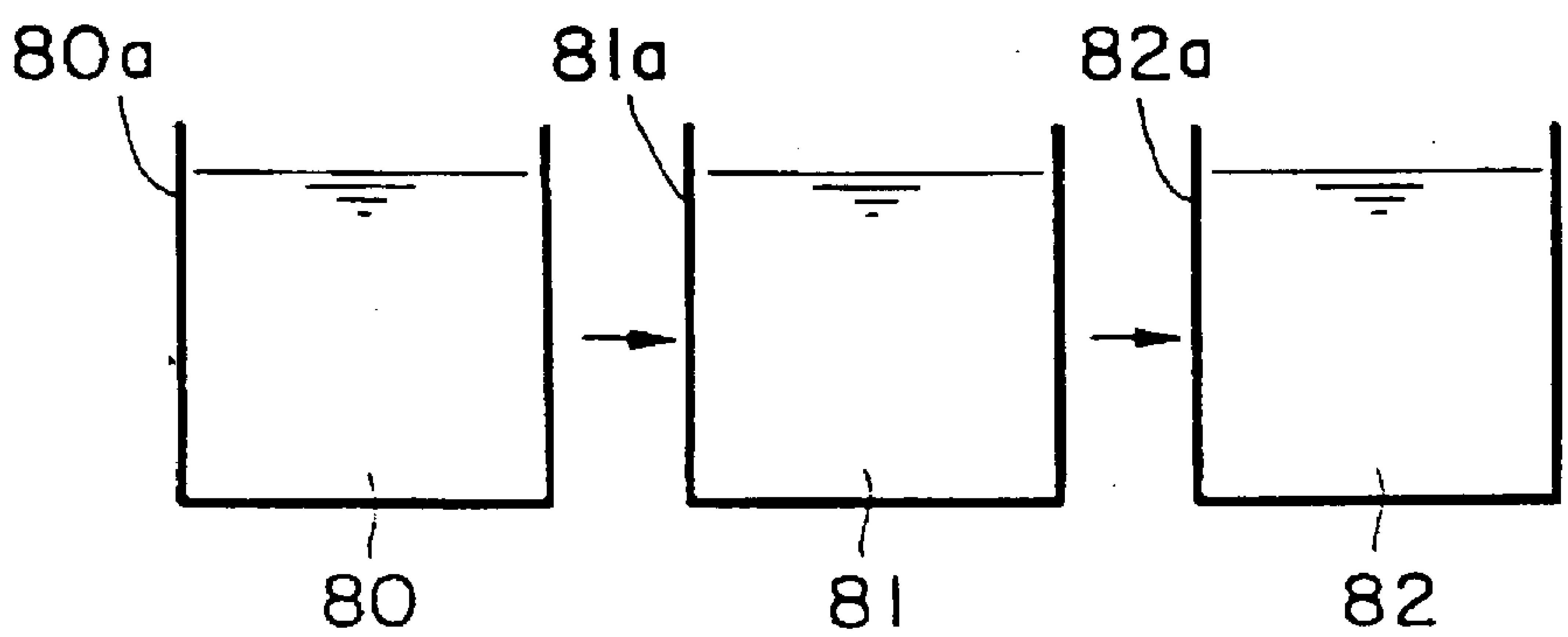


FIG. 15

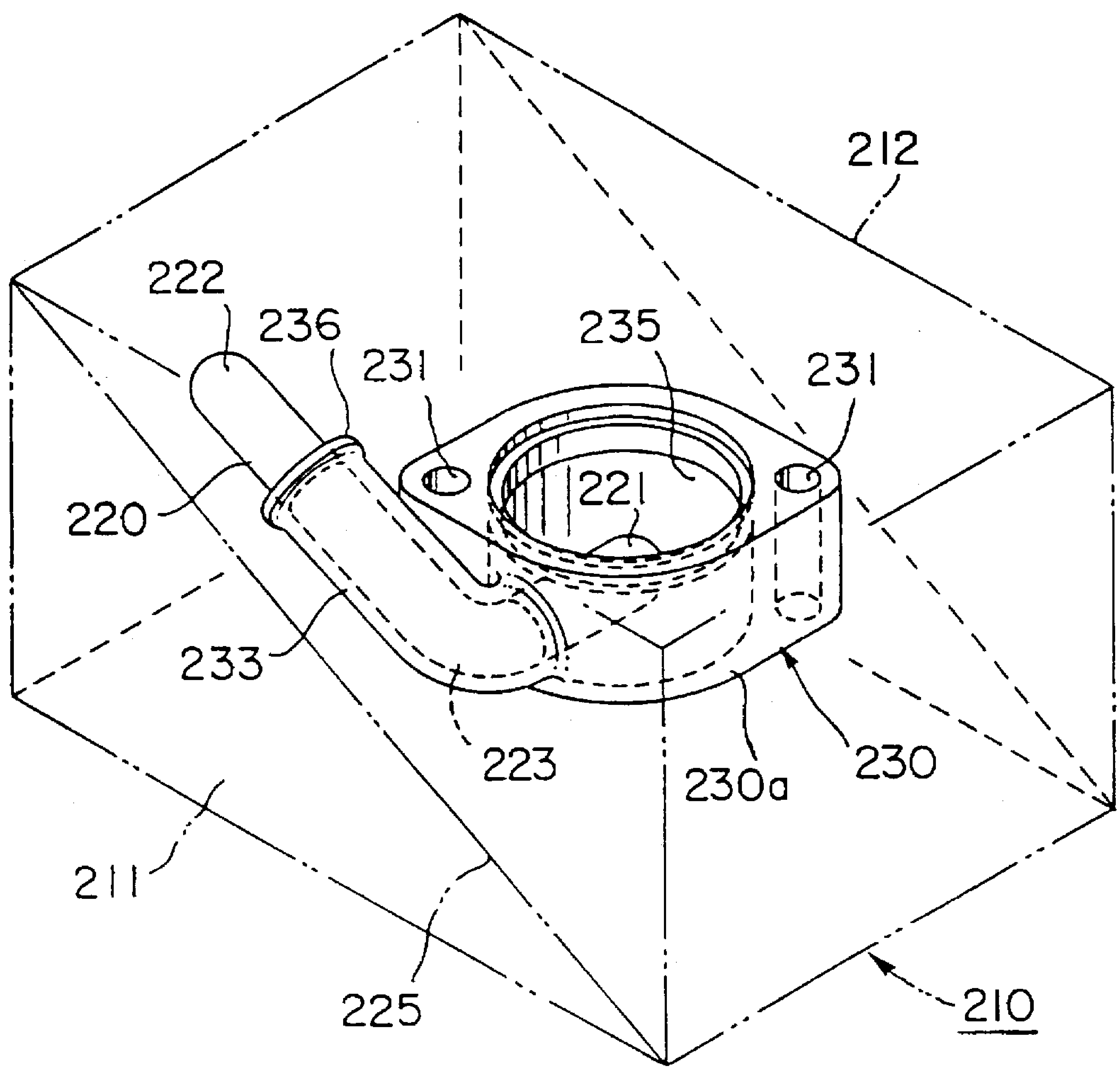


FIG. 16

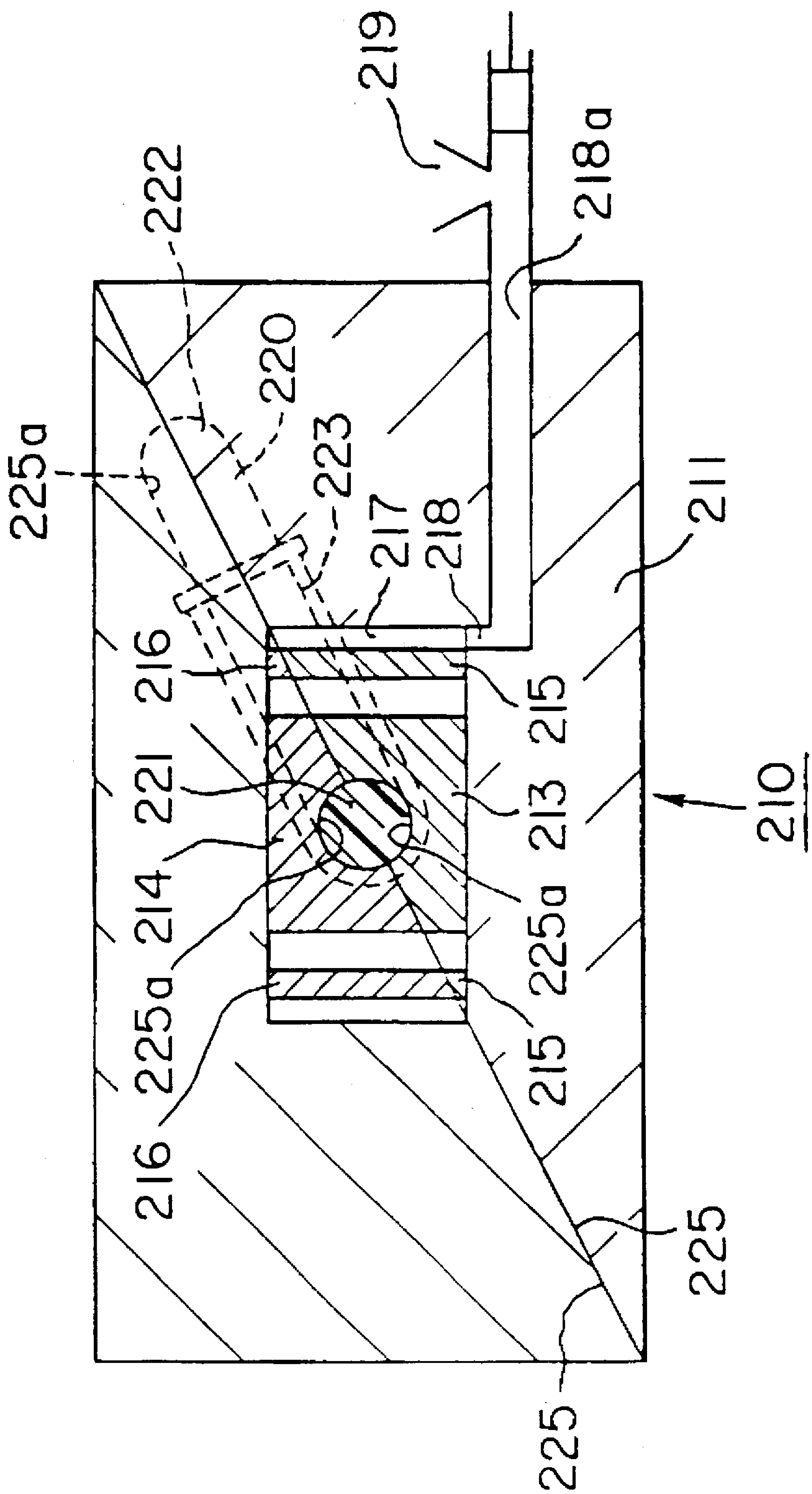

219
222
218a
220
225a
223
217
218
211
216
215
221
213
210
214
225a
225a
216
215
225
225

FIG. 17

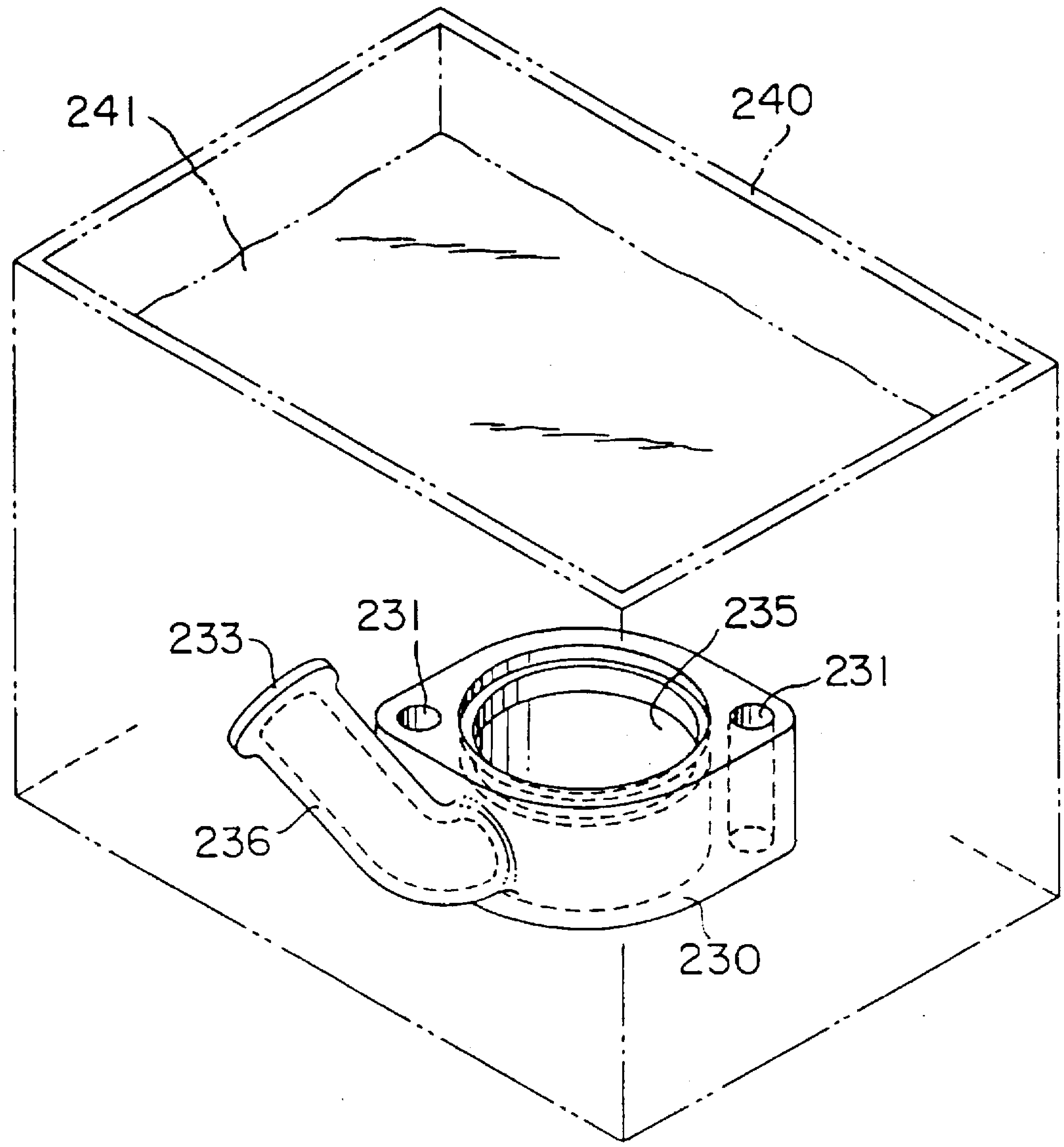
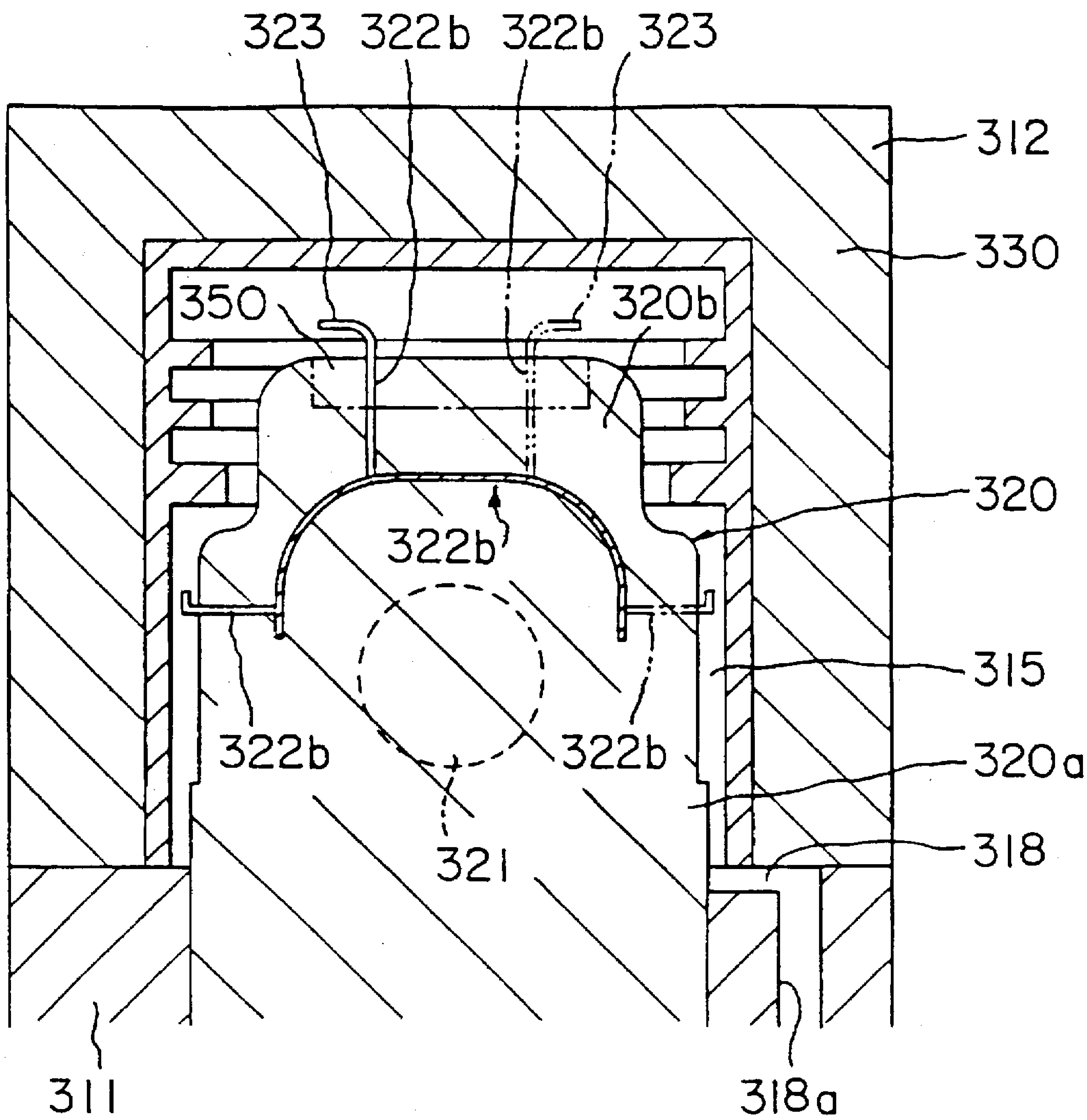
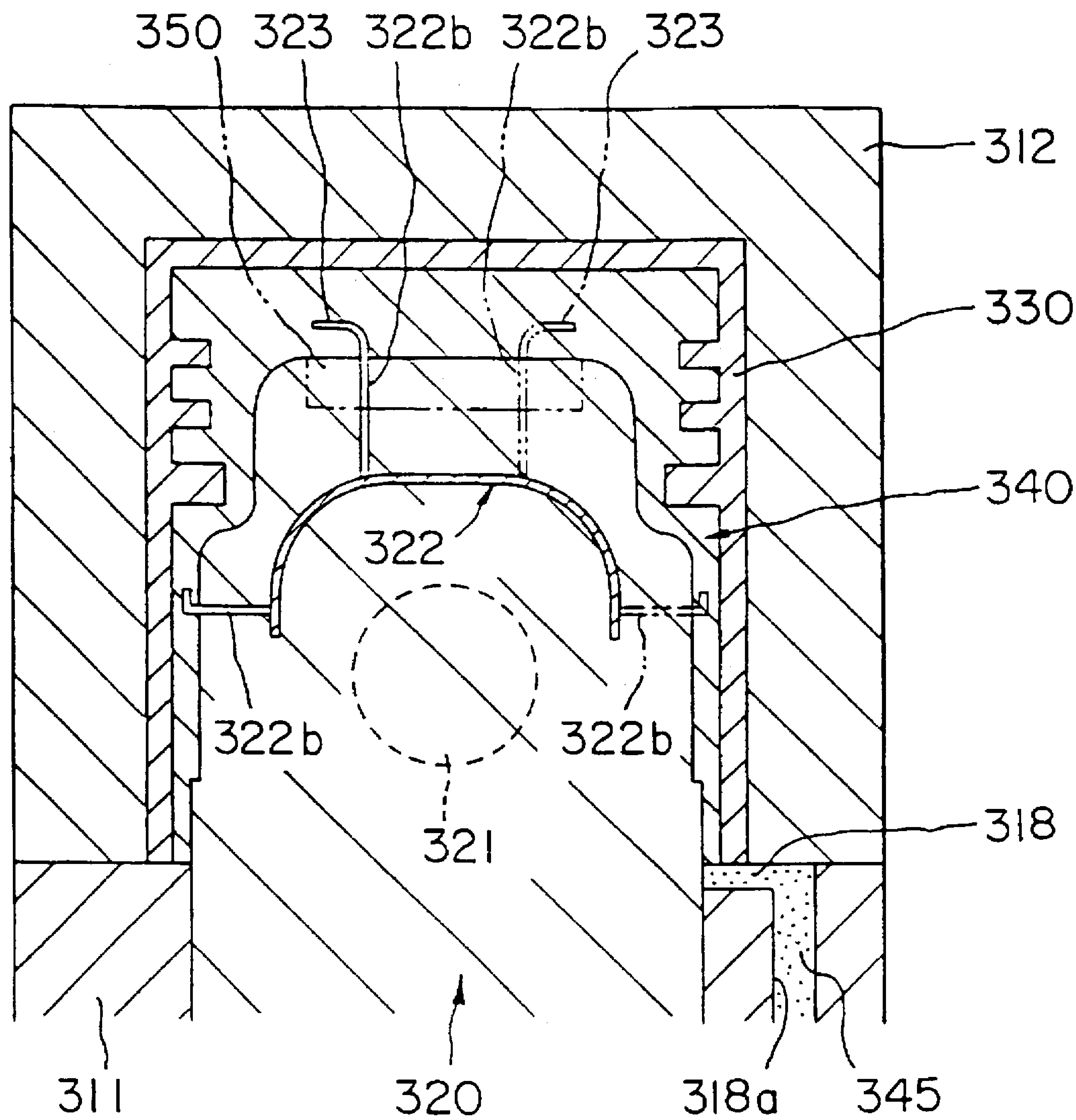


FIG. 18


323
322b
322b
323
312
330
350
320b
320
322b
315
322b
322b
320a
321
318
311
318a

F I G. 19


350
323
322b
322b
323
312
330
340
322
322b
322b
321
318
311
320
318a
345

F I G. 20

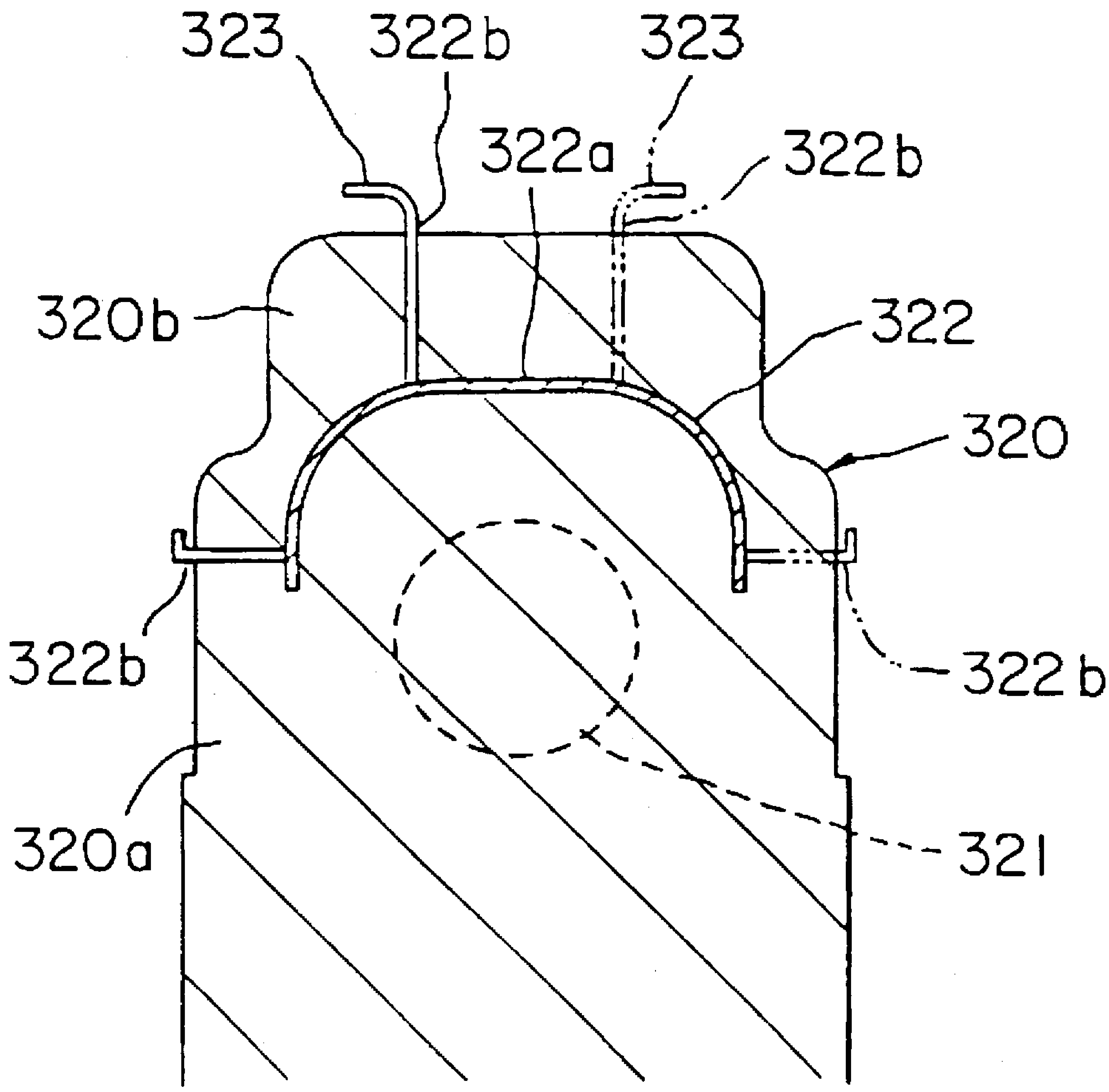


FIG. 21

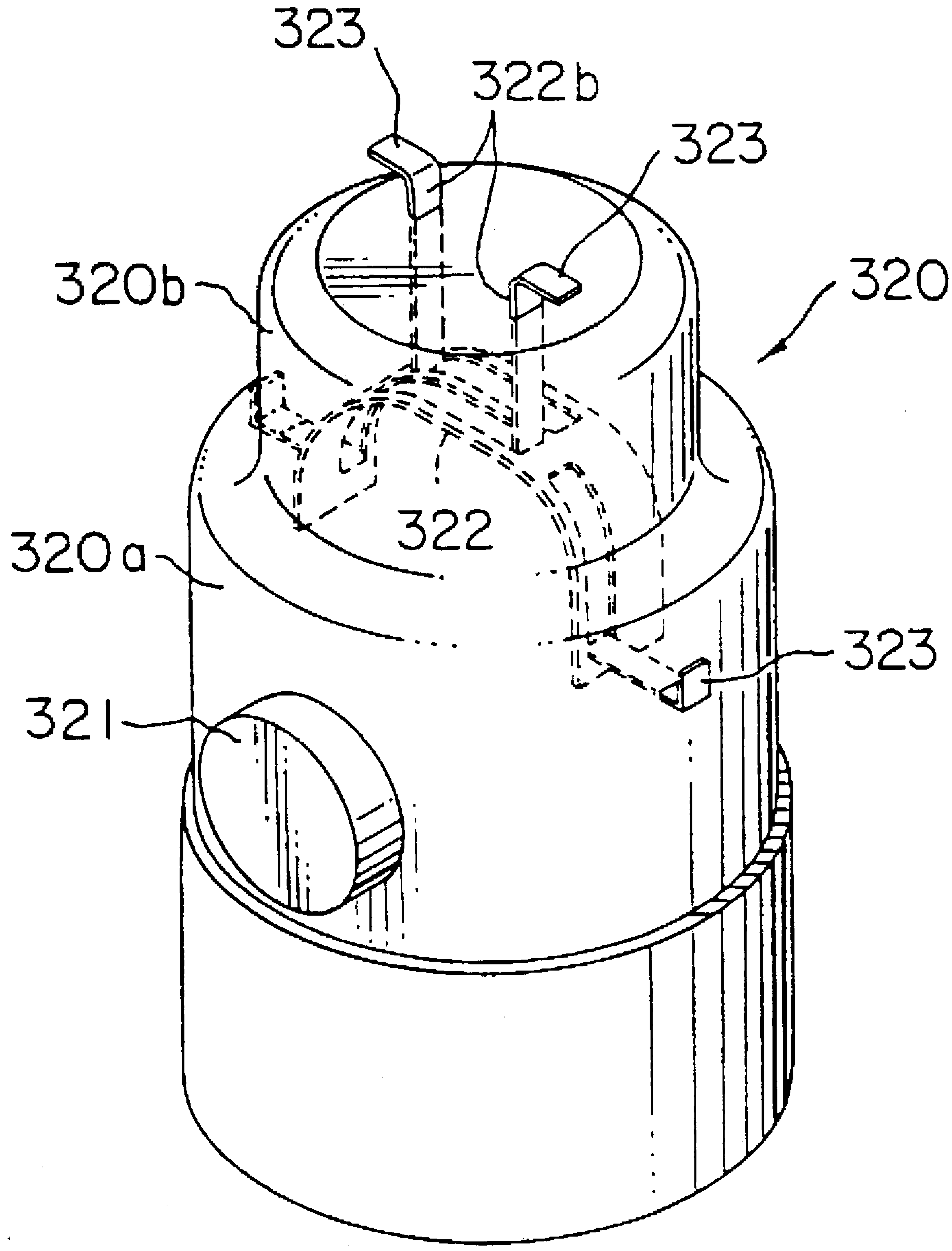


FIG. 22

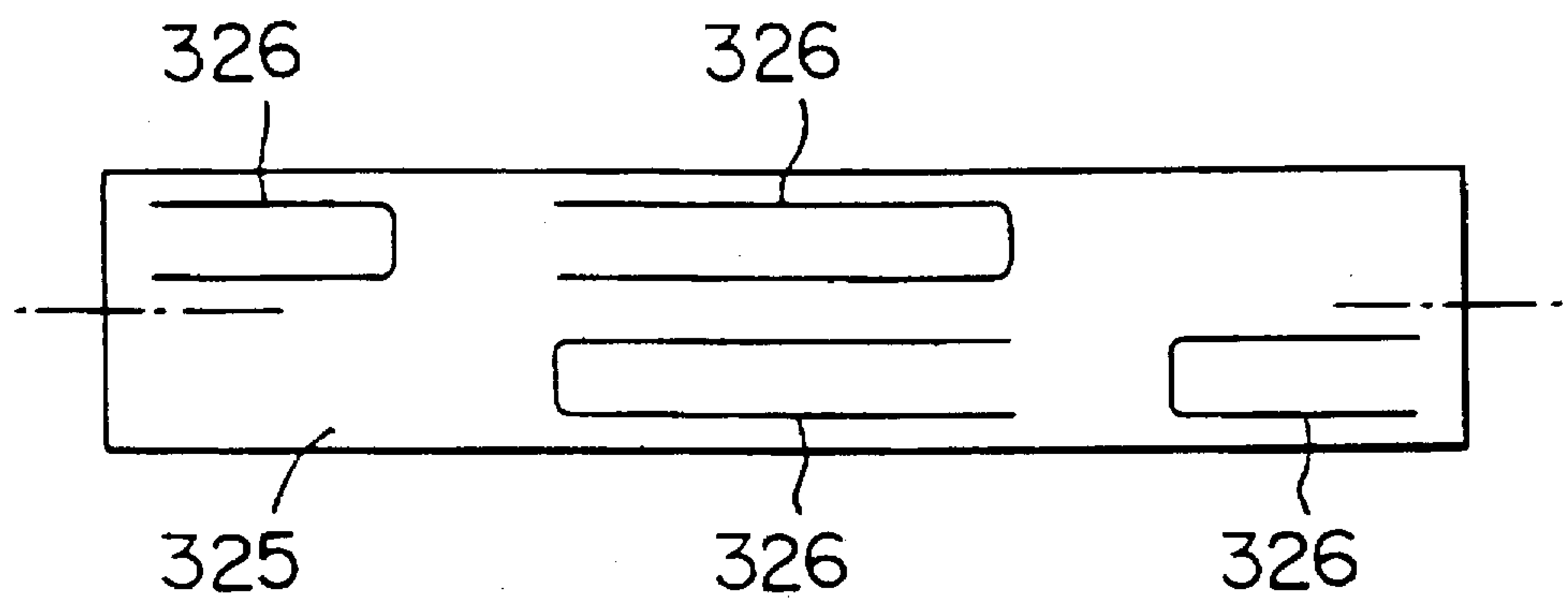


FIG. 23 A

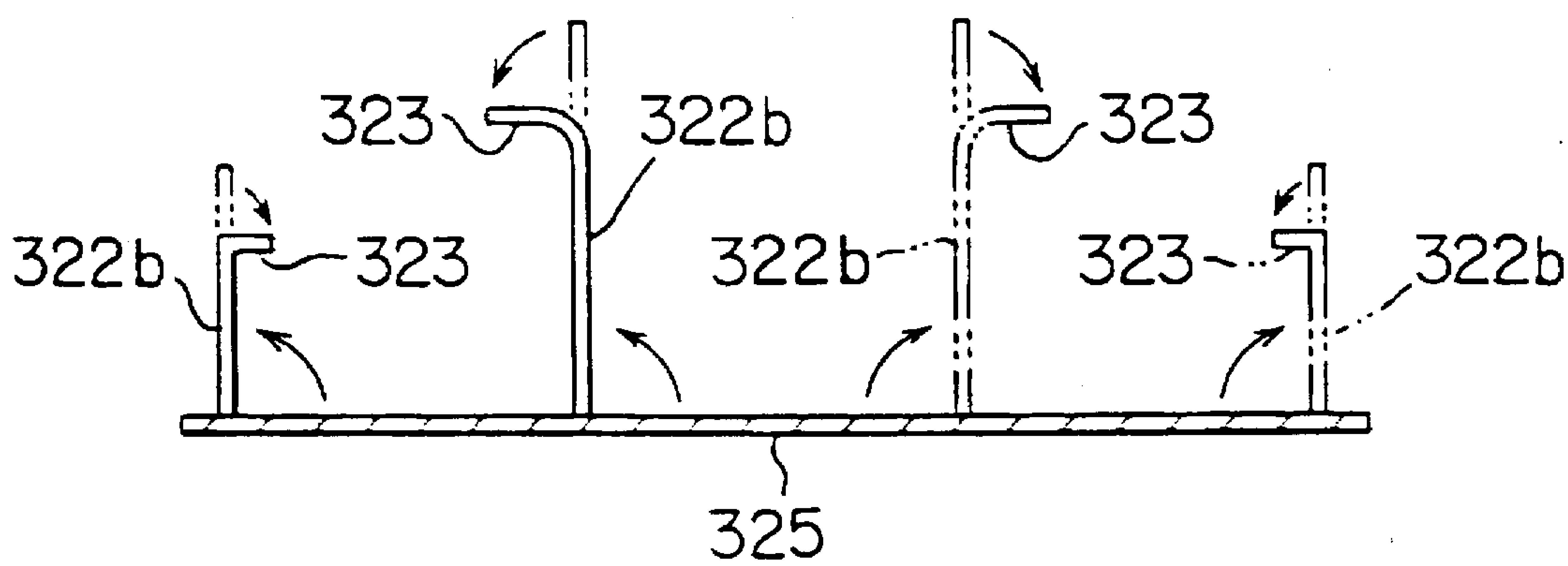


FIG. 23 B

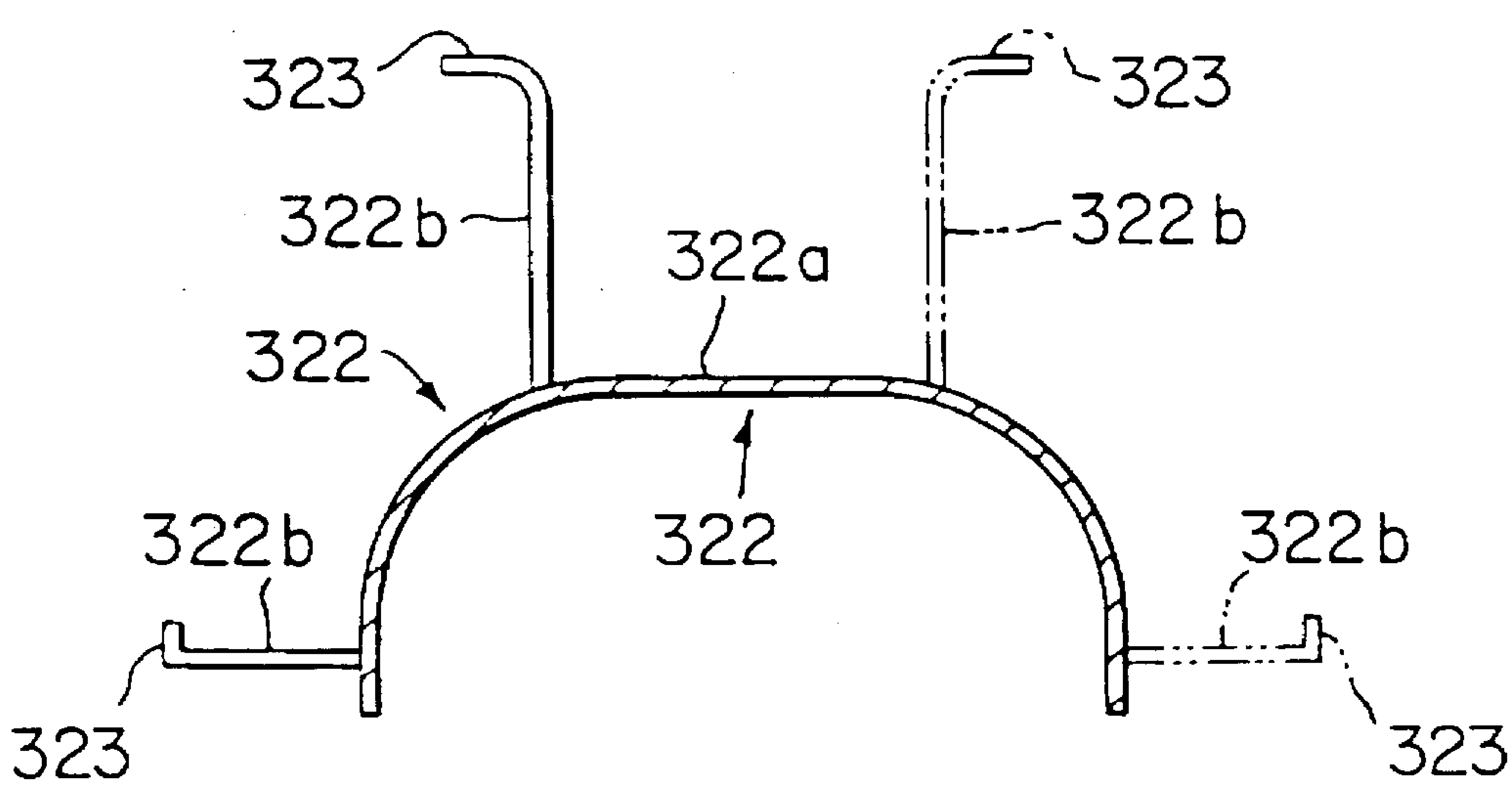


FIG. 23 C

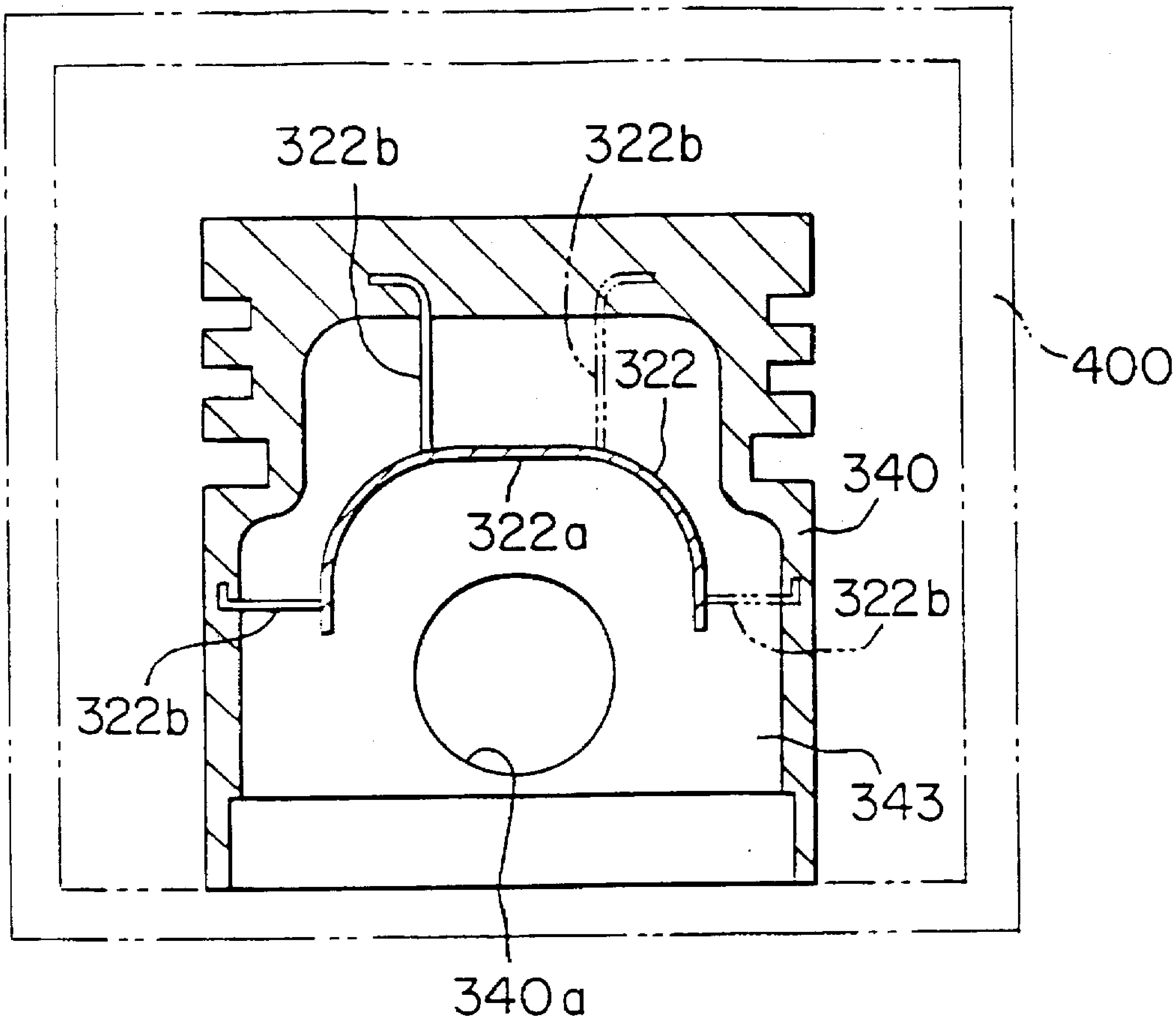

322b
322b
322
400
340
322a
322b
322b
343
340a

FIG. 24

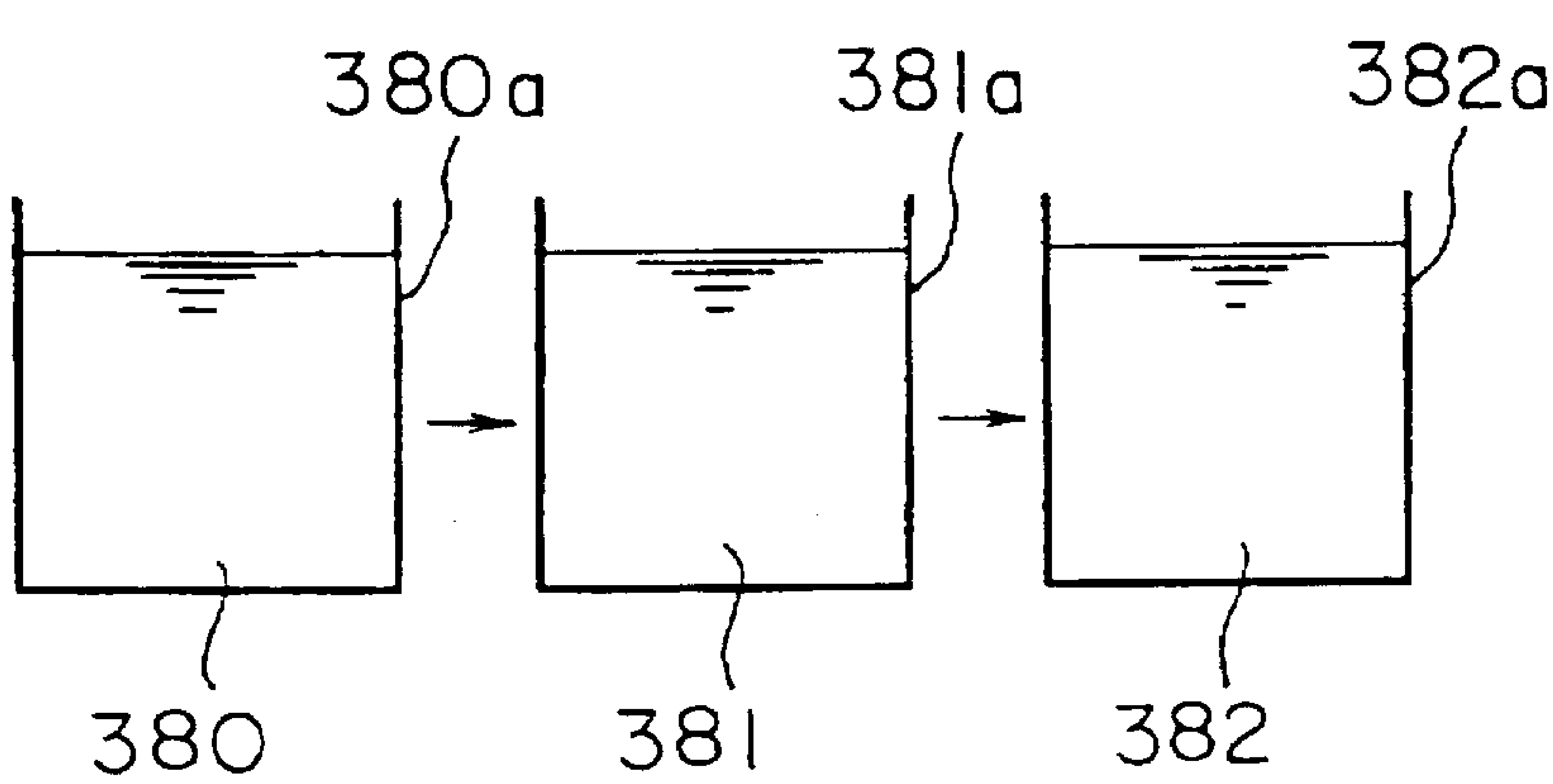

380a
381a
382a
380
381
382

FIG. 25

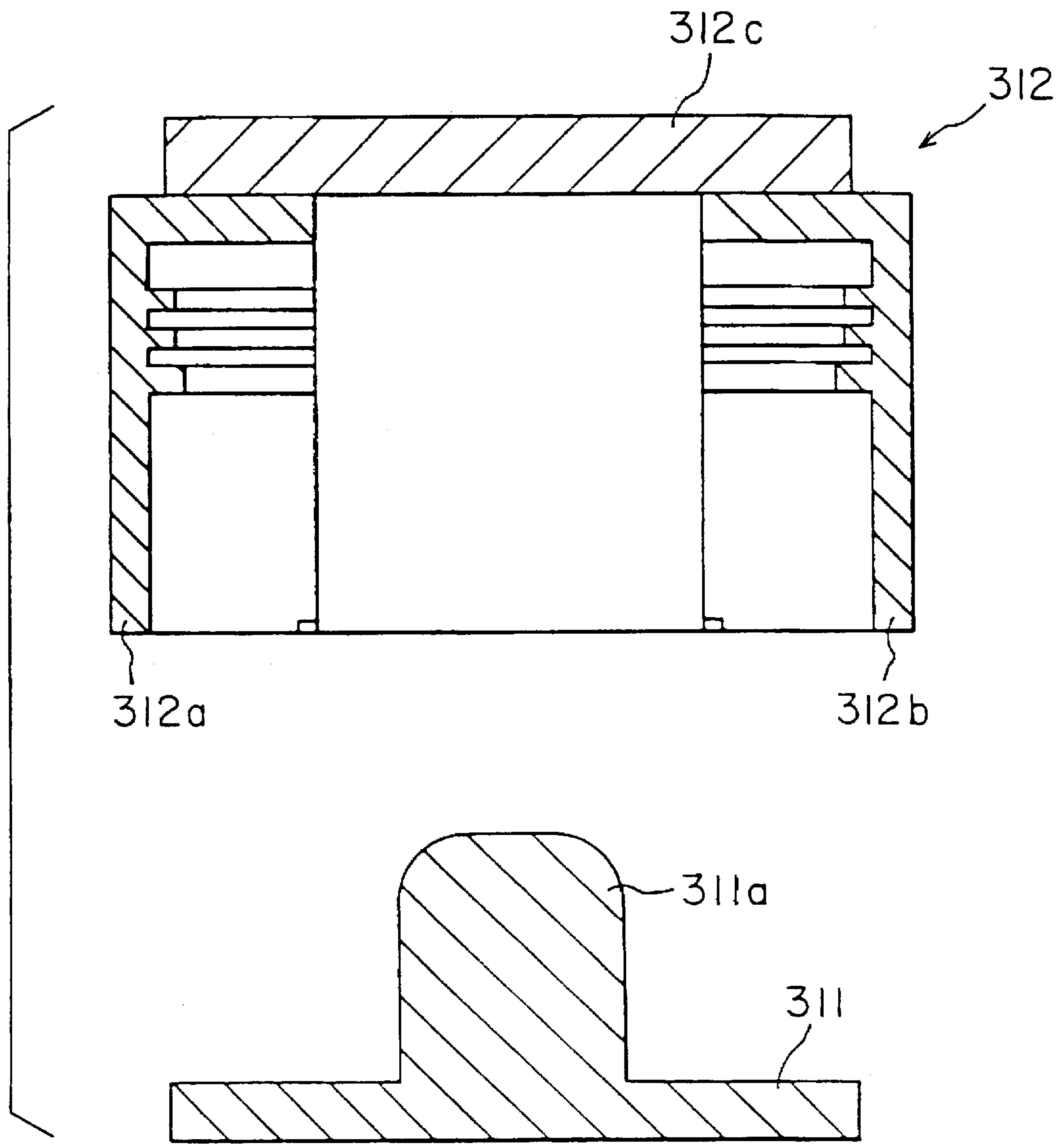
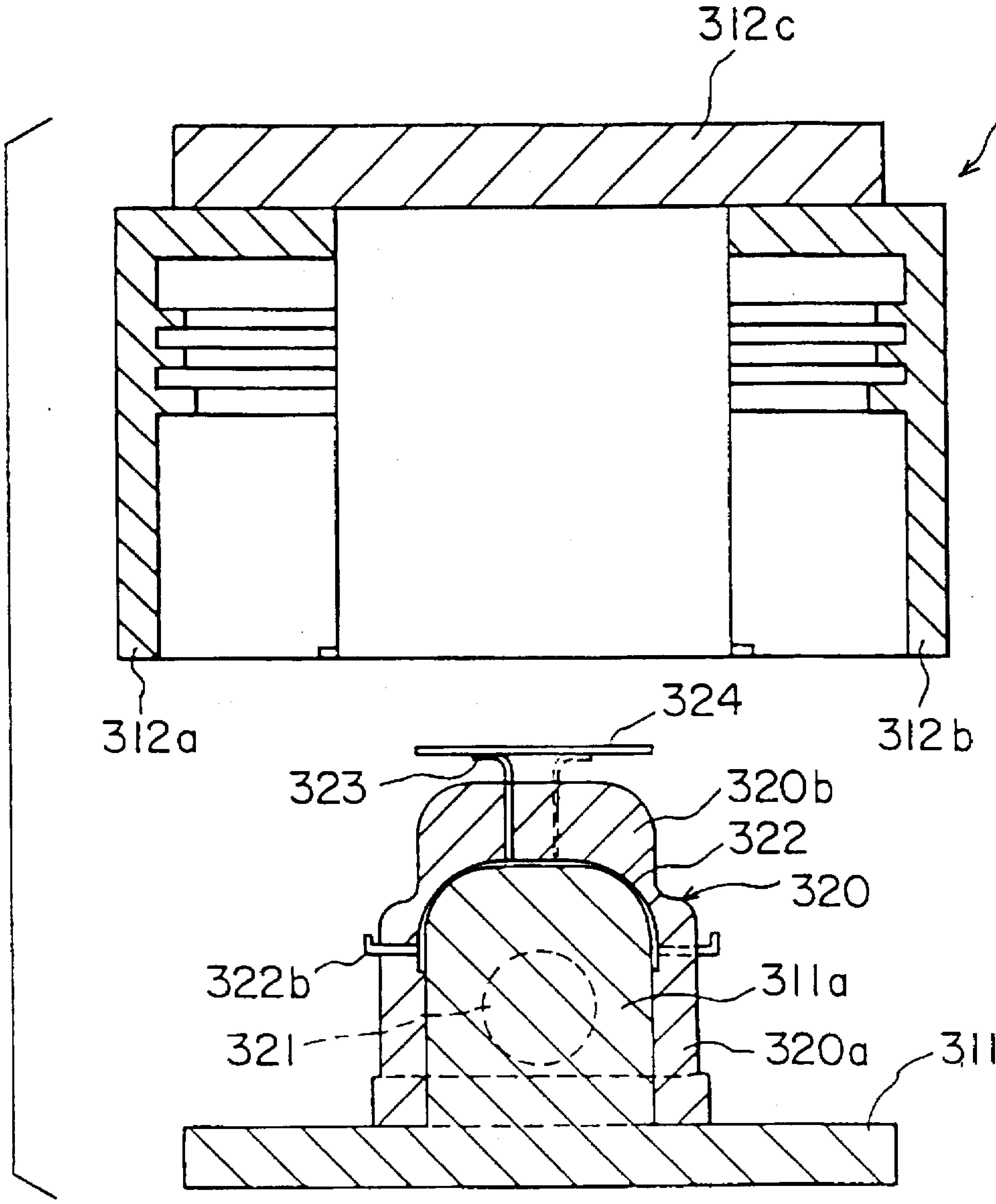


FIG. 26



F I G. 27

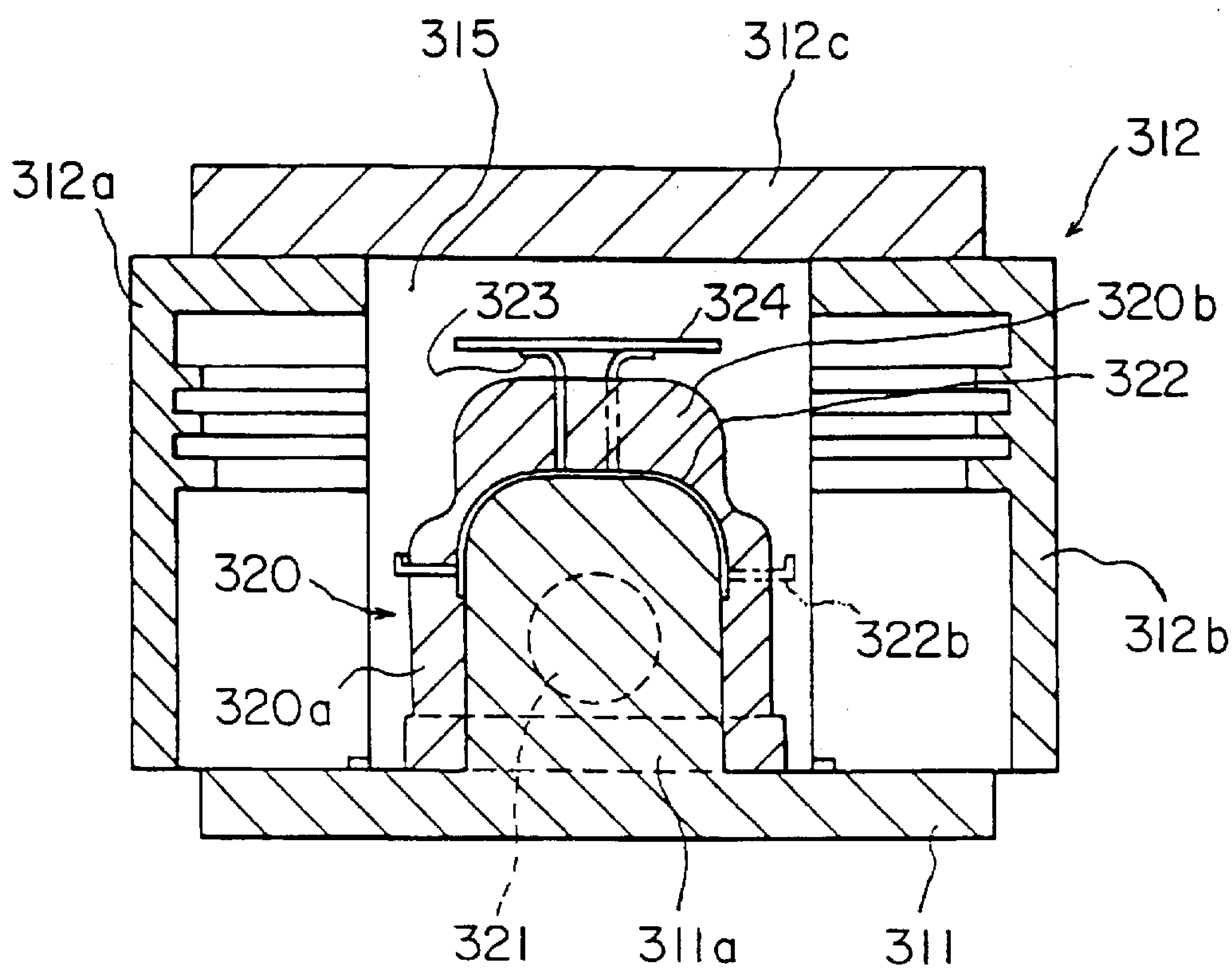

315
312c
312
312a
323
324
320b
322
320
322b
312b
320a
321
311a
311

FIG. 28

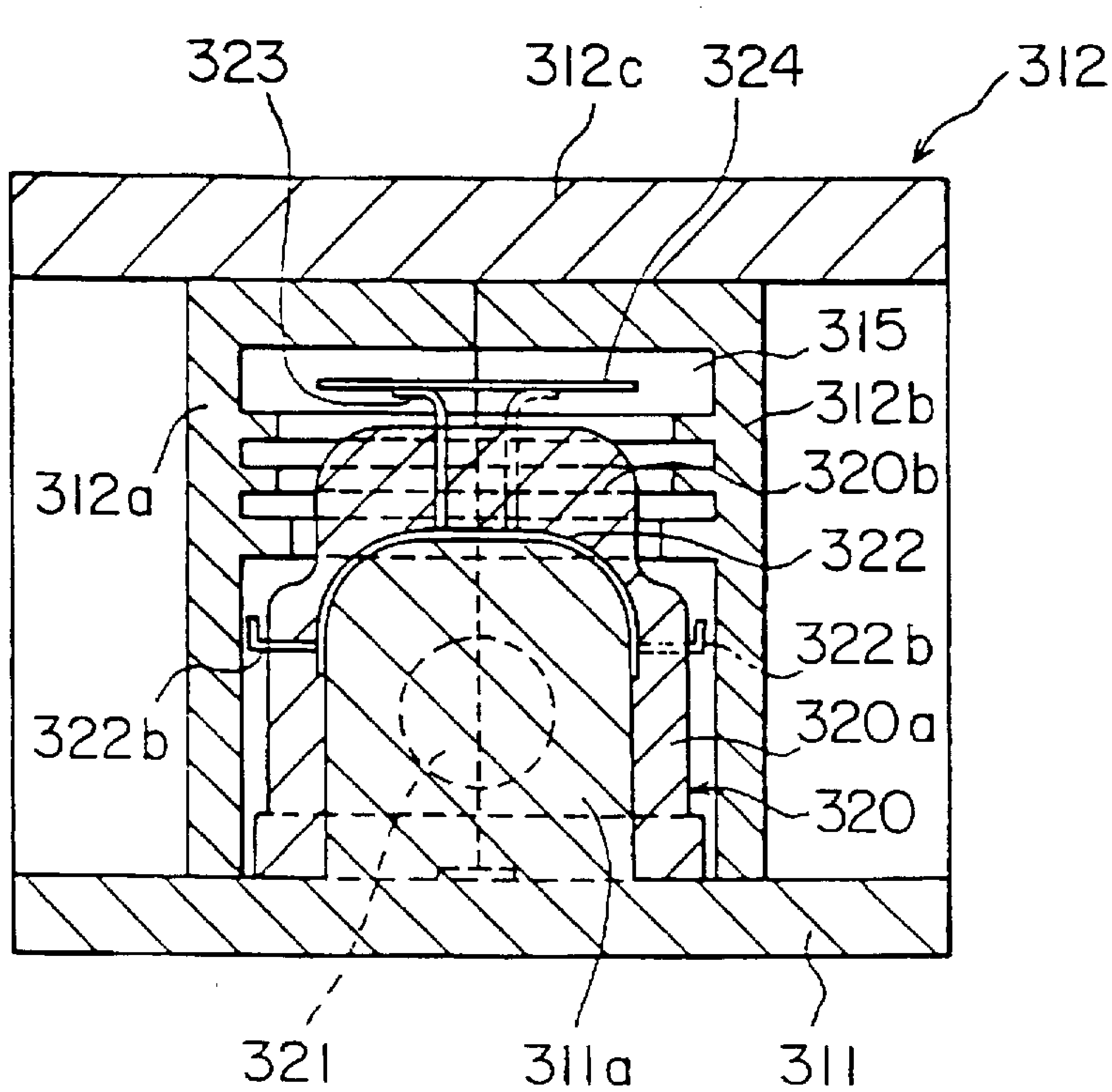

323
312c
324
312
315
312b
312a
320b
322
322b
322b
320a
320
321
311a
311

FIG. 29

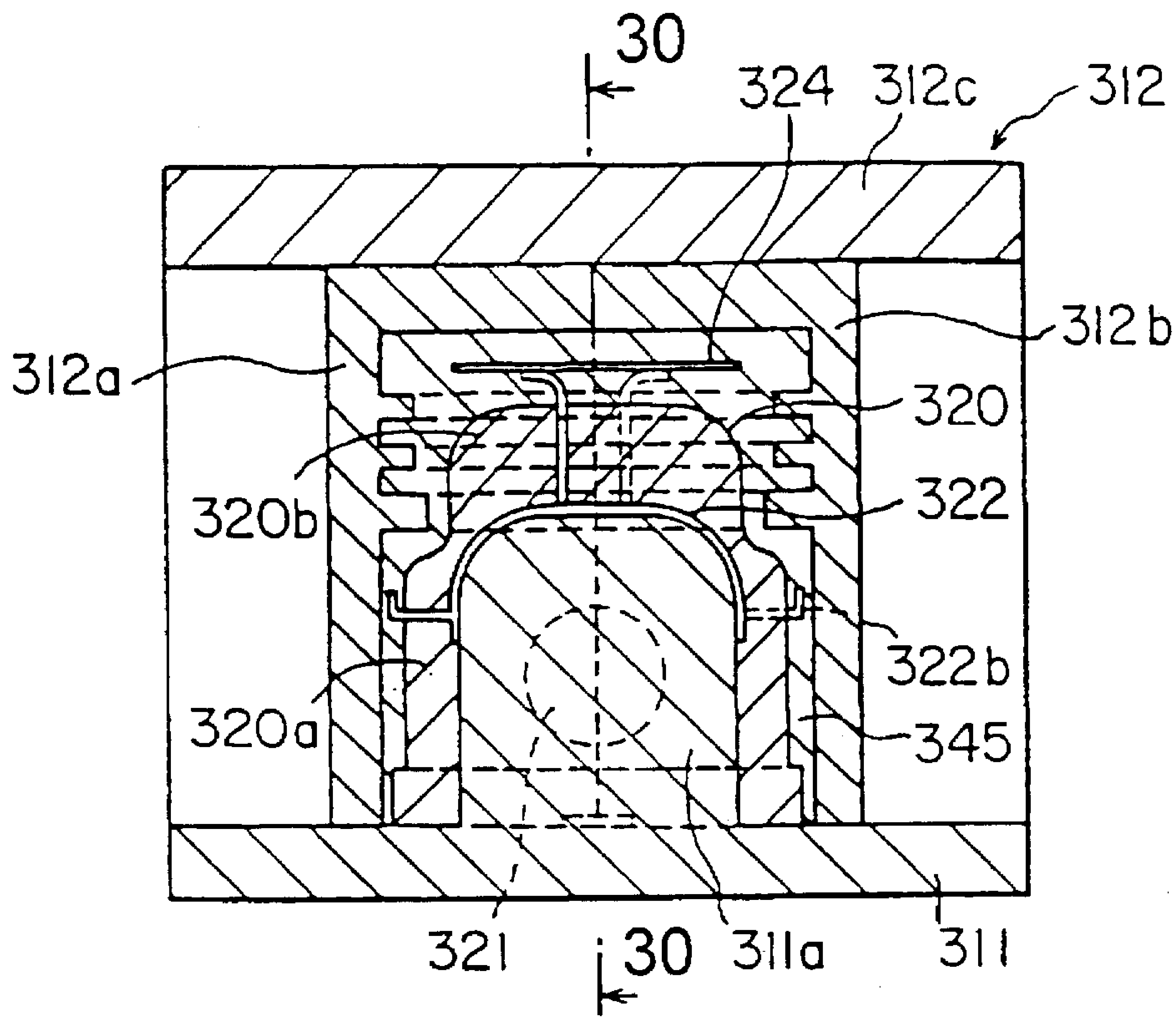


FIG. 30A

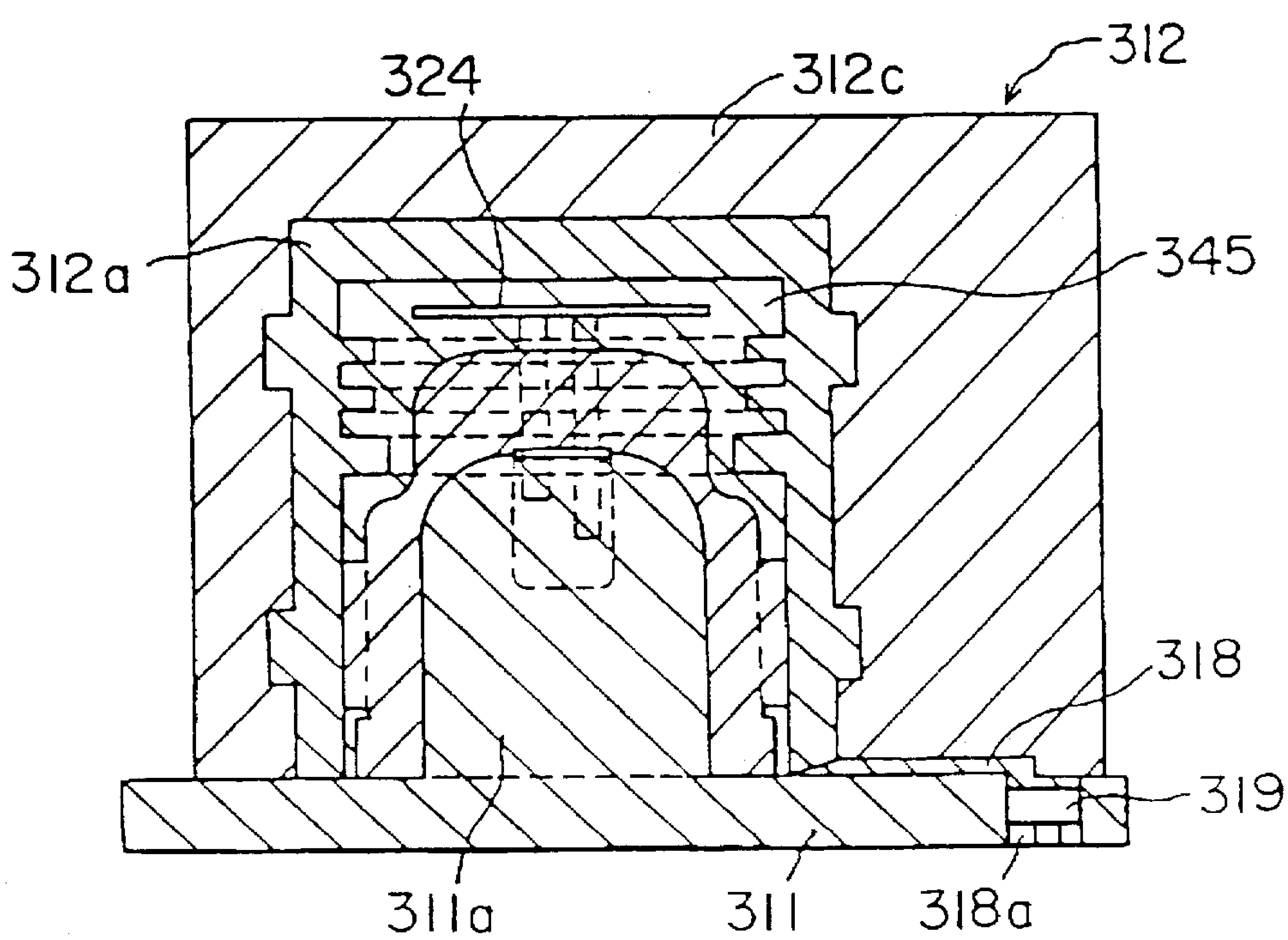


FIG. 30B

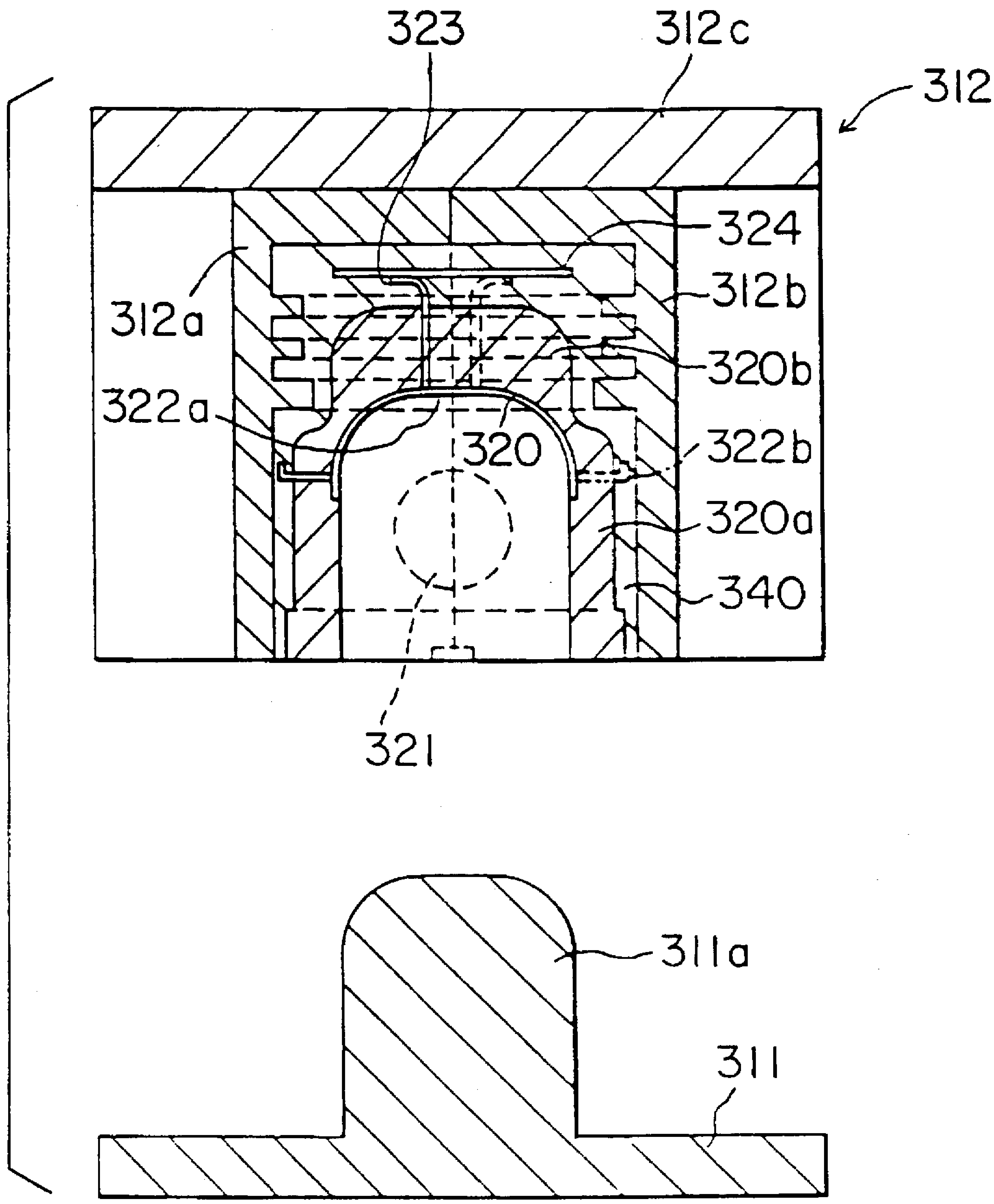

323
312c
312
324
312b
312a
320b
322a
320
322b
320a
340
321
311a
311

FIG. 31

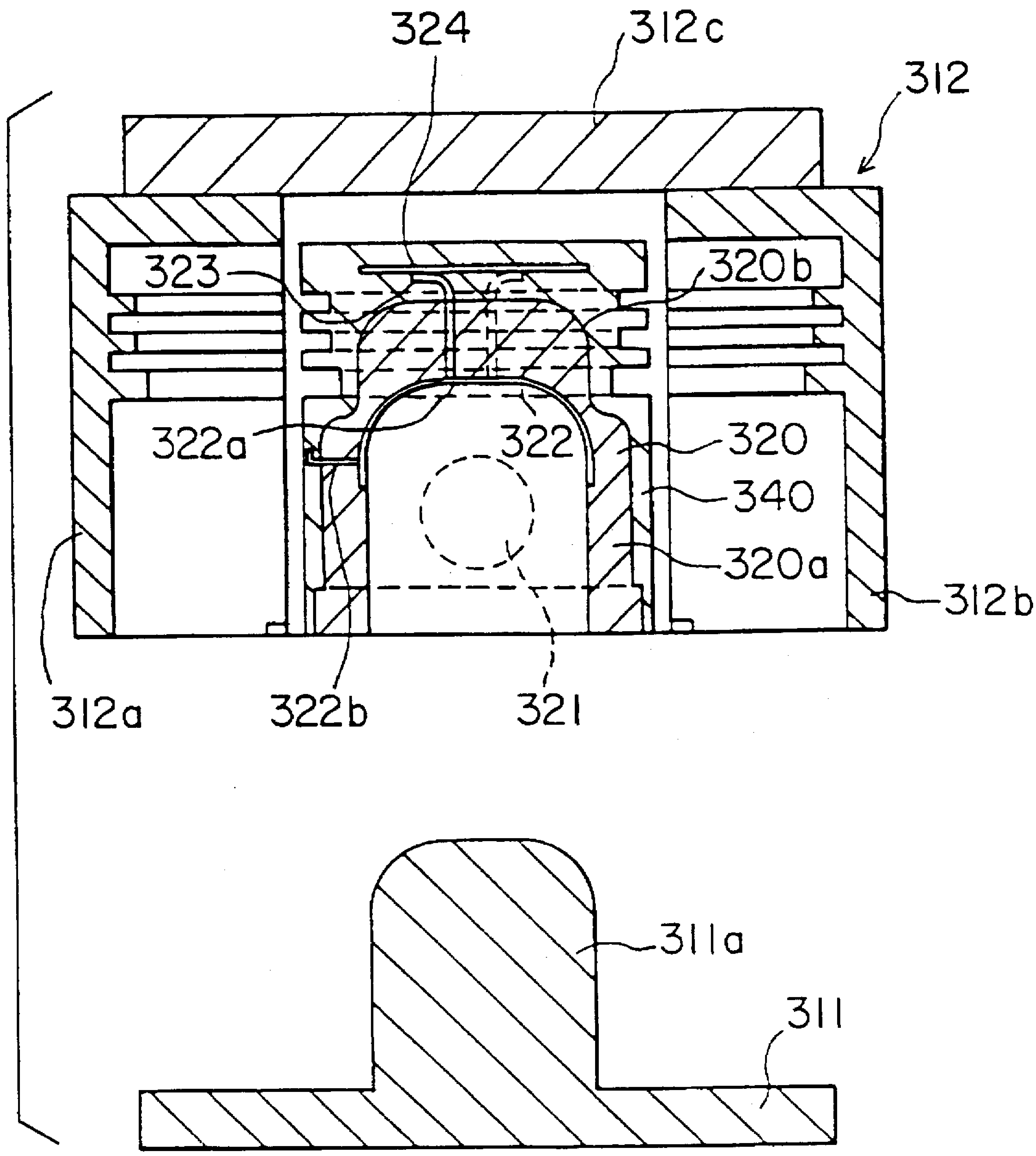

324
312c
312
323
320b
322a
322
320
340
320a
312b
312a
322b
321
311a
311

FIG. 32

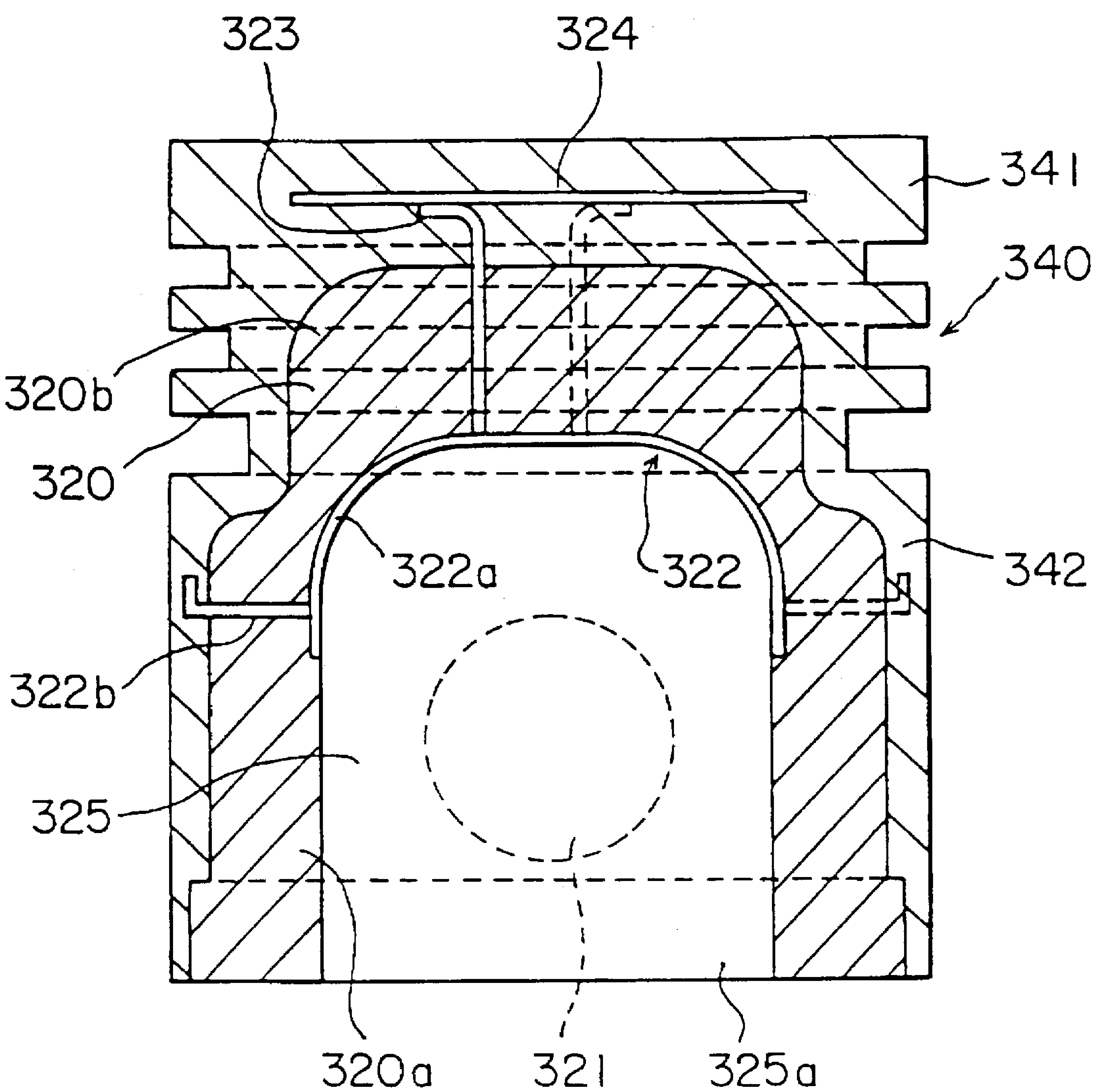


FIG. 33

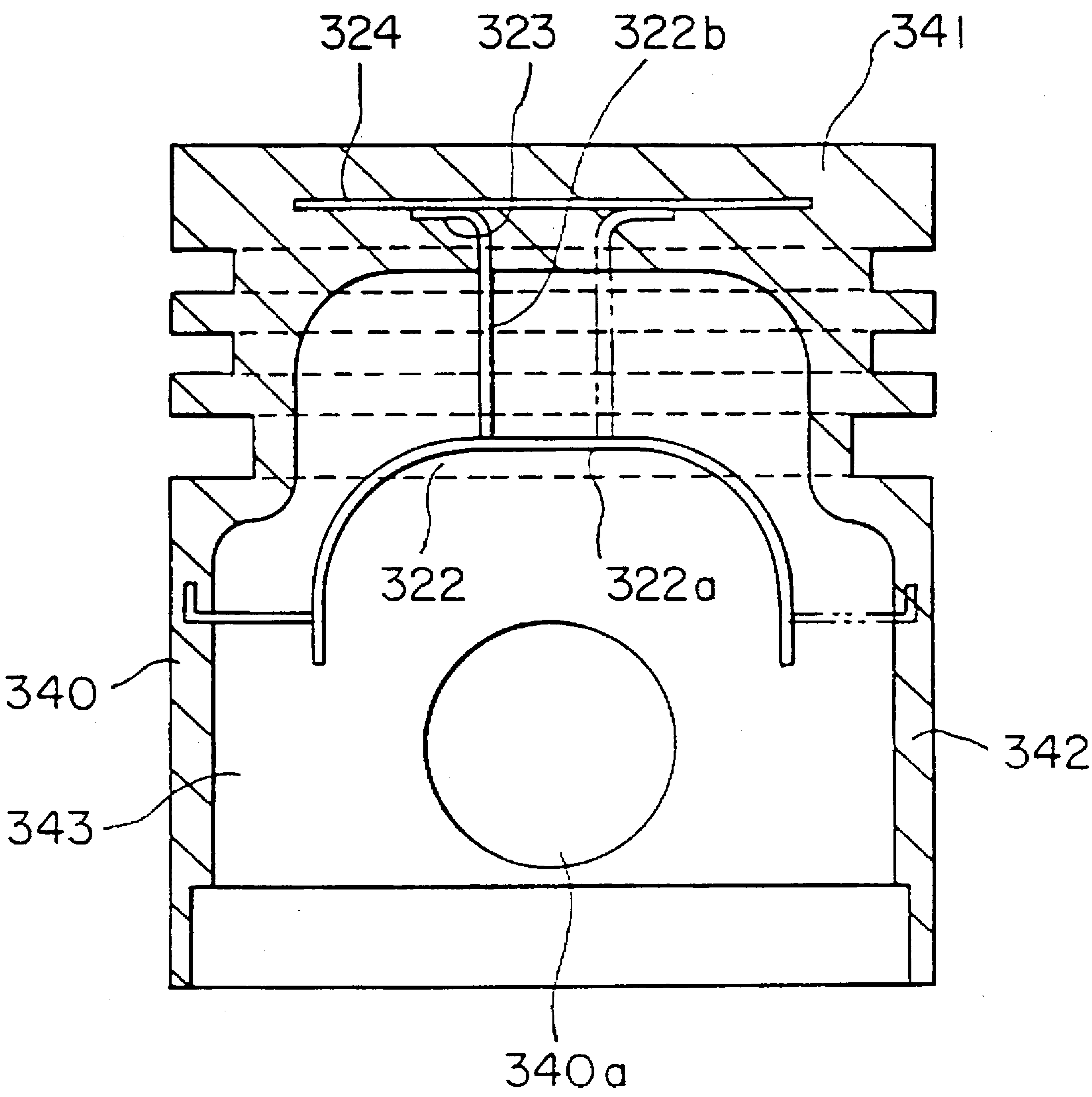


FIG. 34

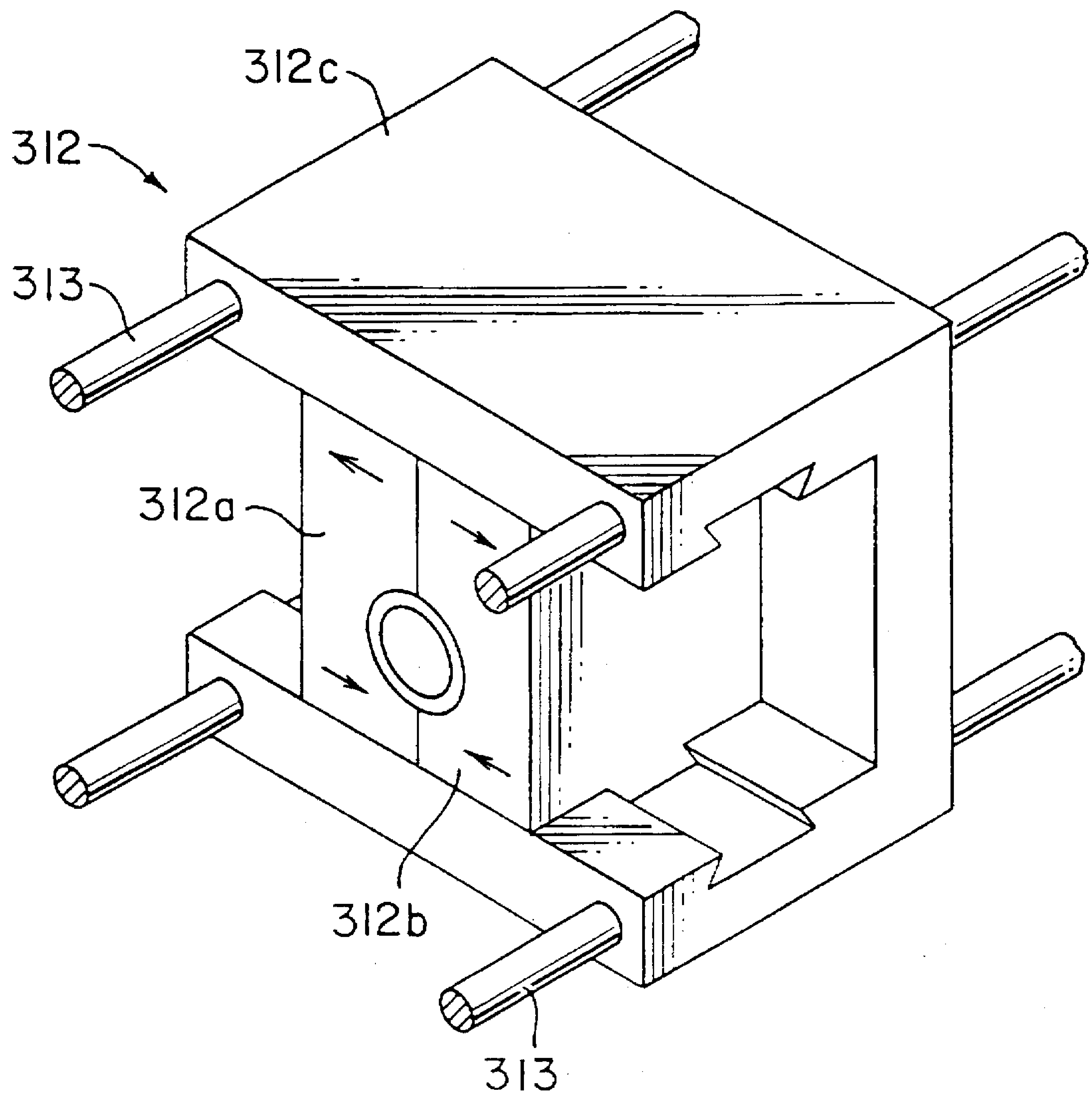


FIG. 35

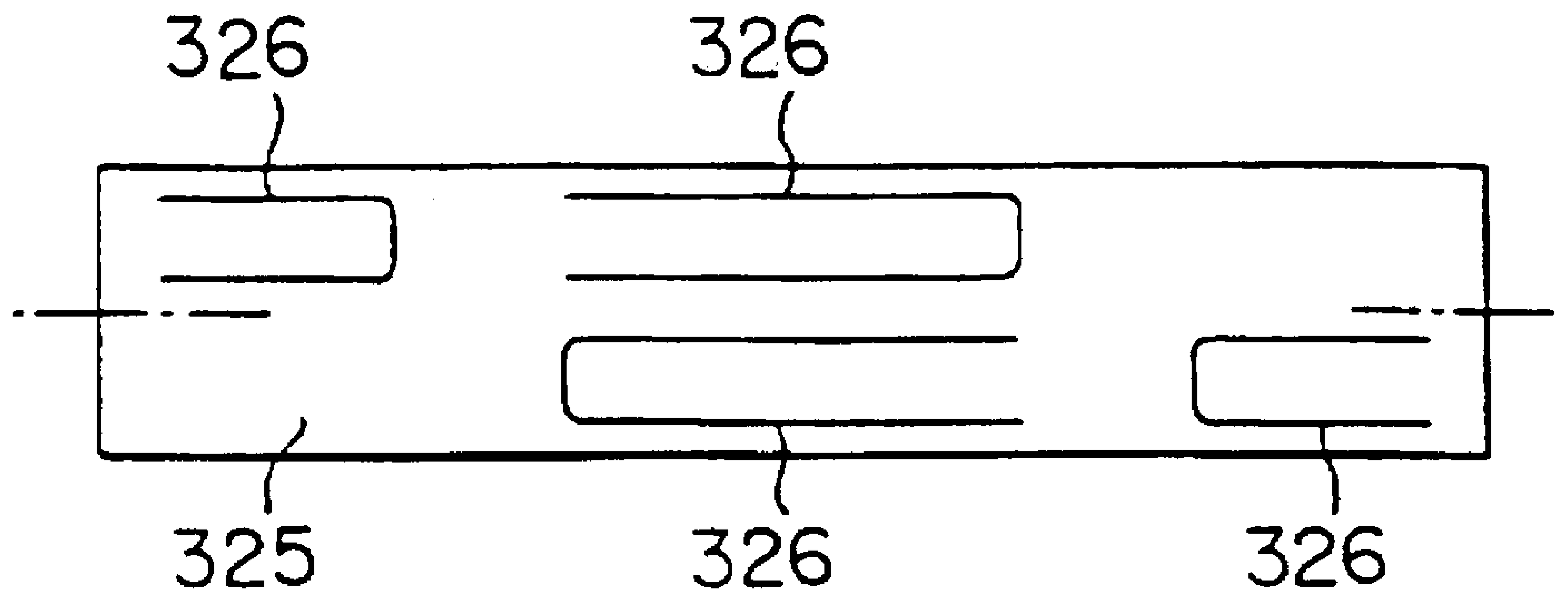


FIG. 36A

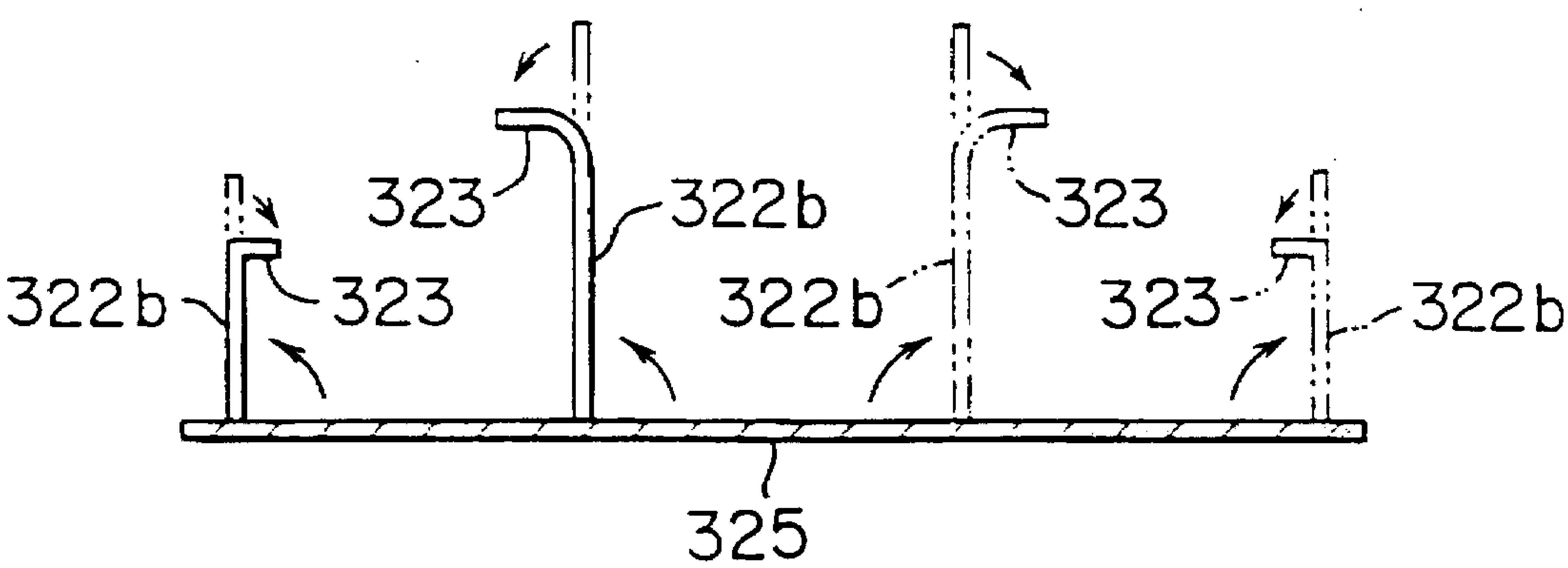


FIG. 36B

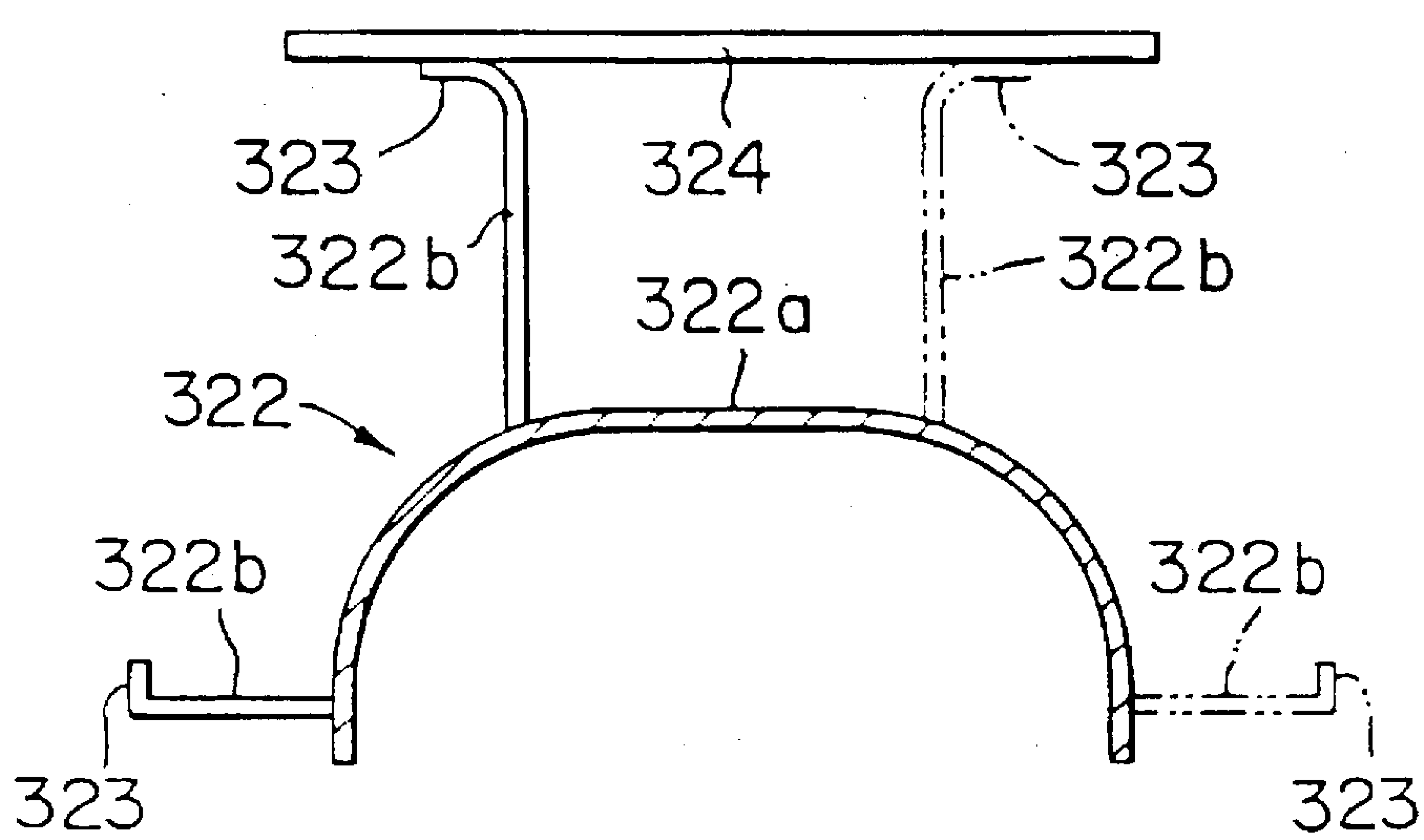


FIG. 36C

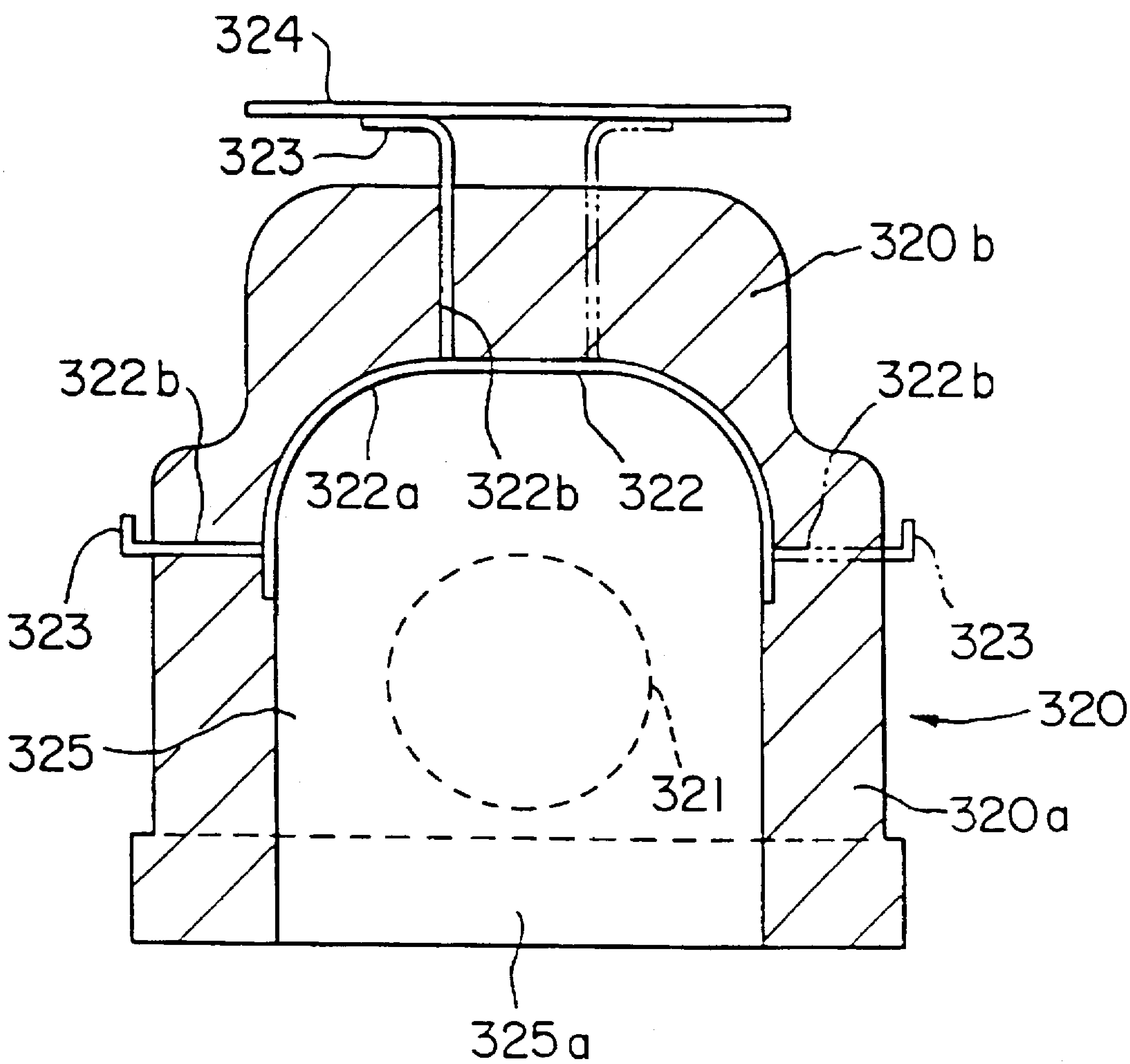

324
323
320 b
322 b
322 b
322a
322b
322
323
323
320
325
321
320 a
325 a

FIG. 37

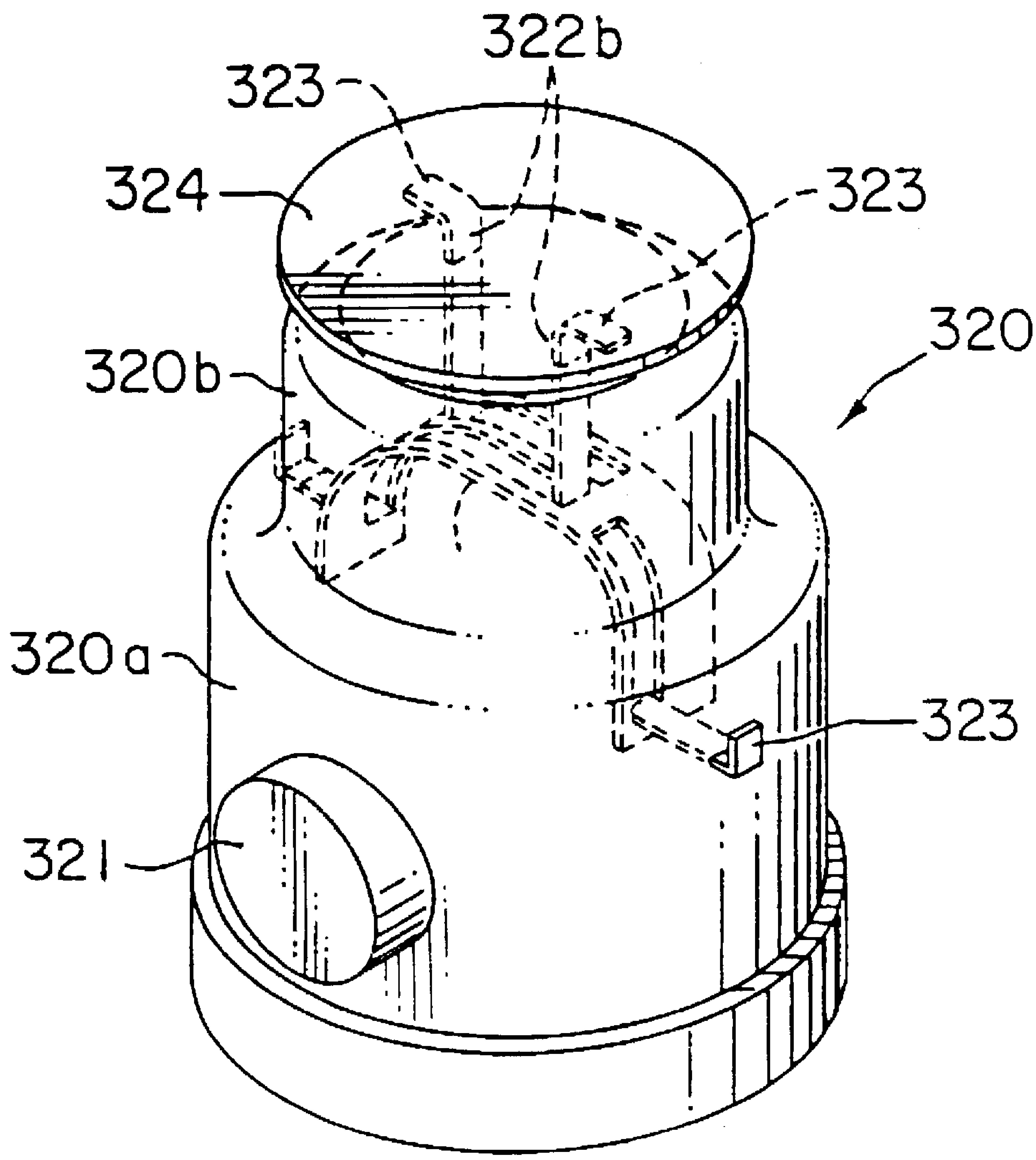


FIG. 38

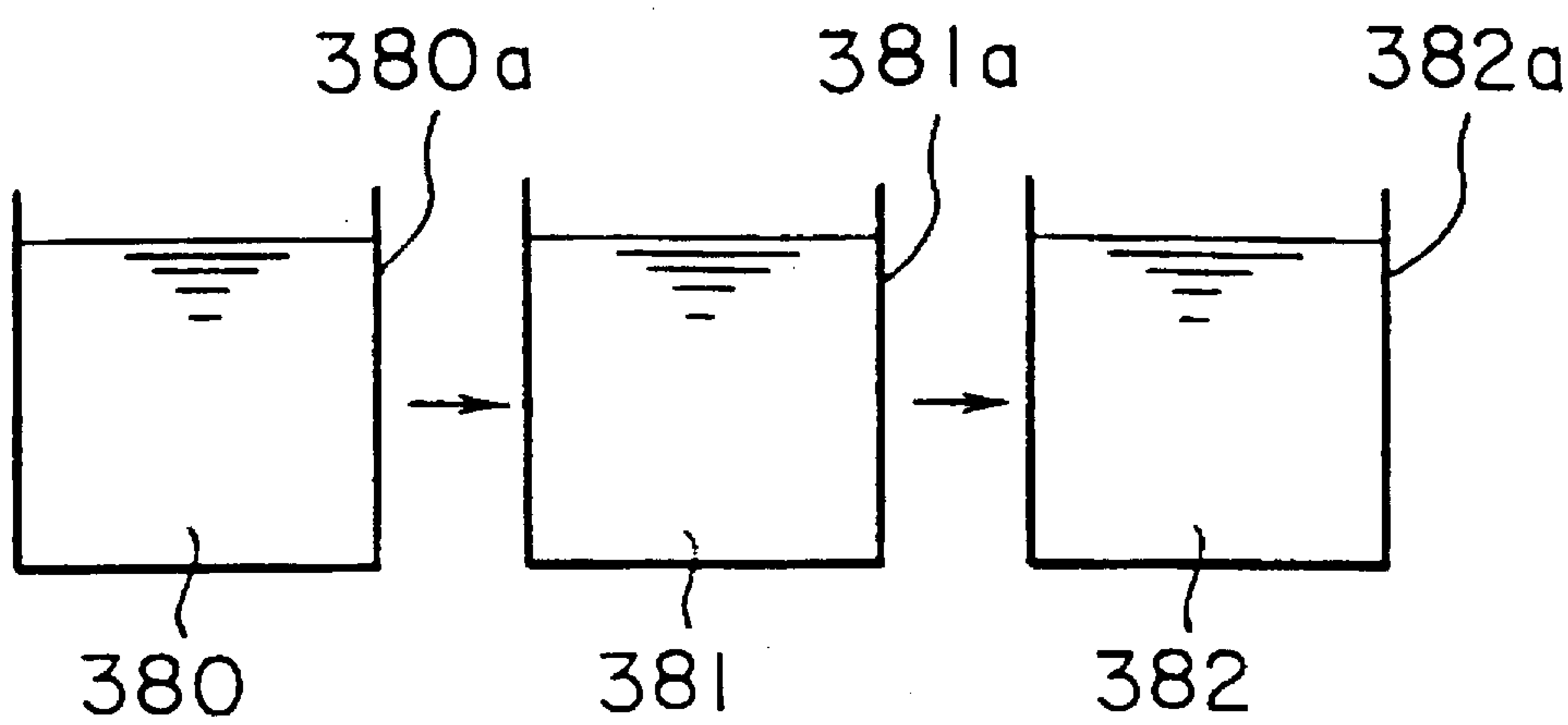


FIG. 39A

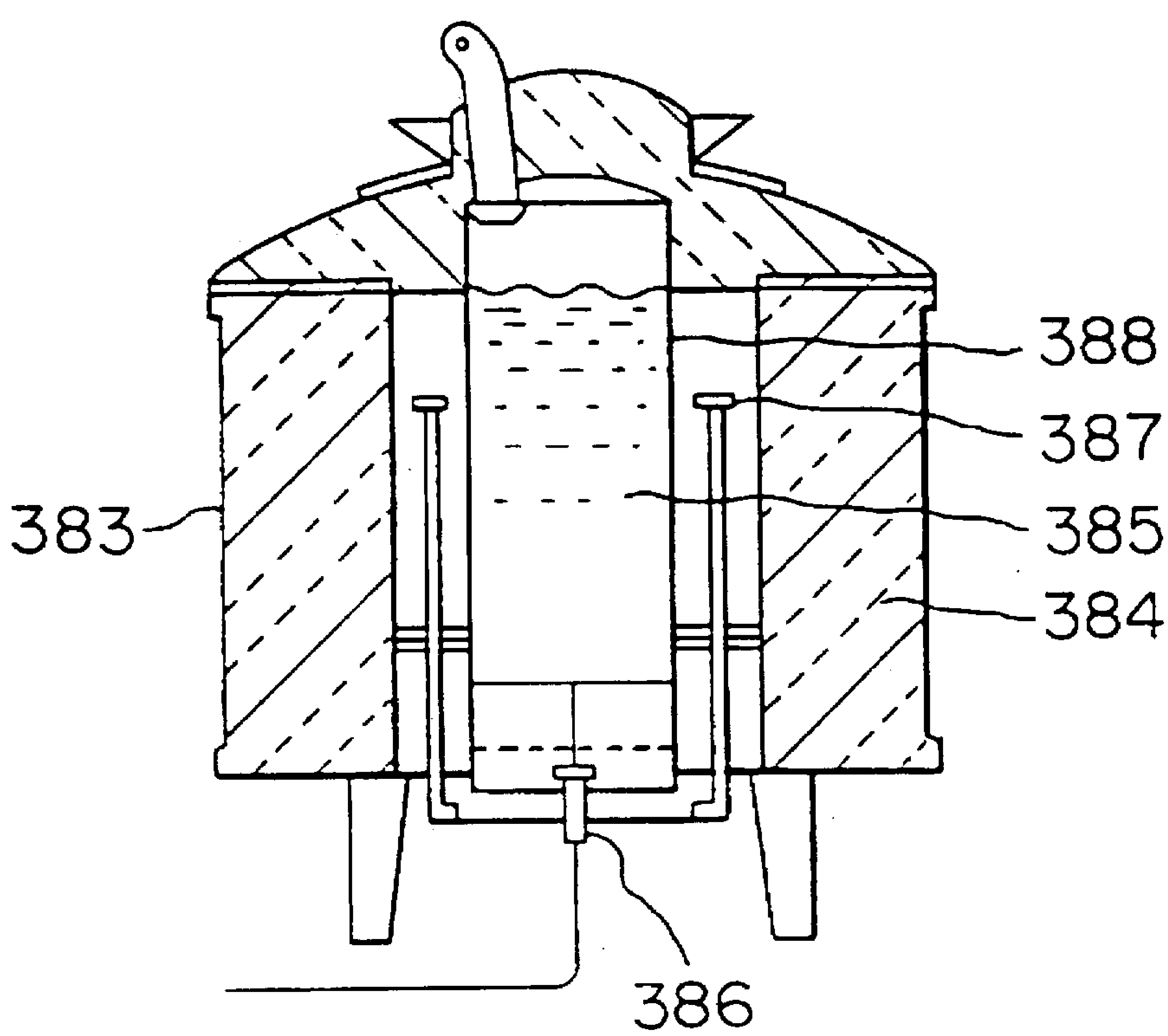


FIG. 39B

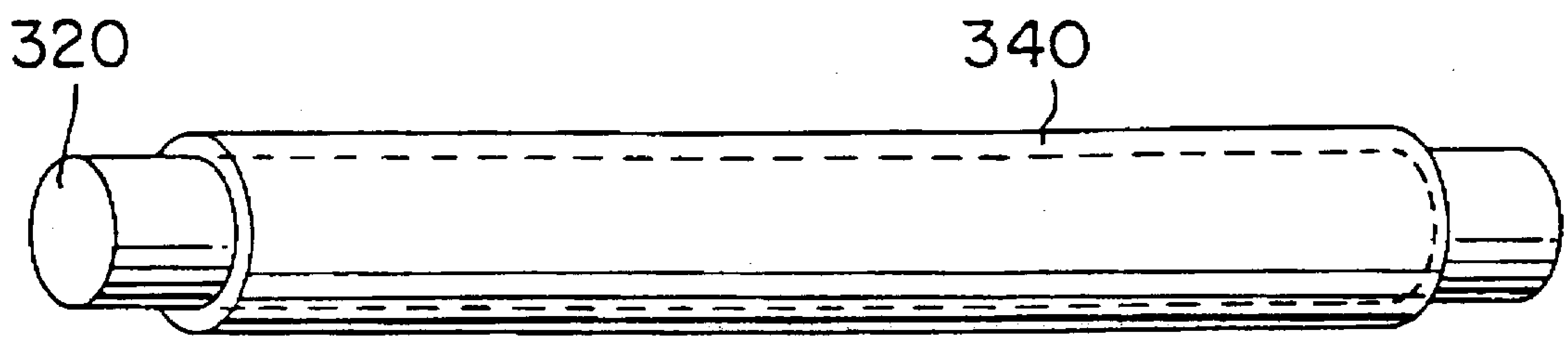


FIG. 40A

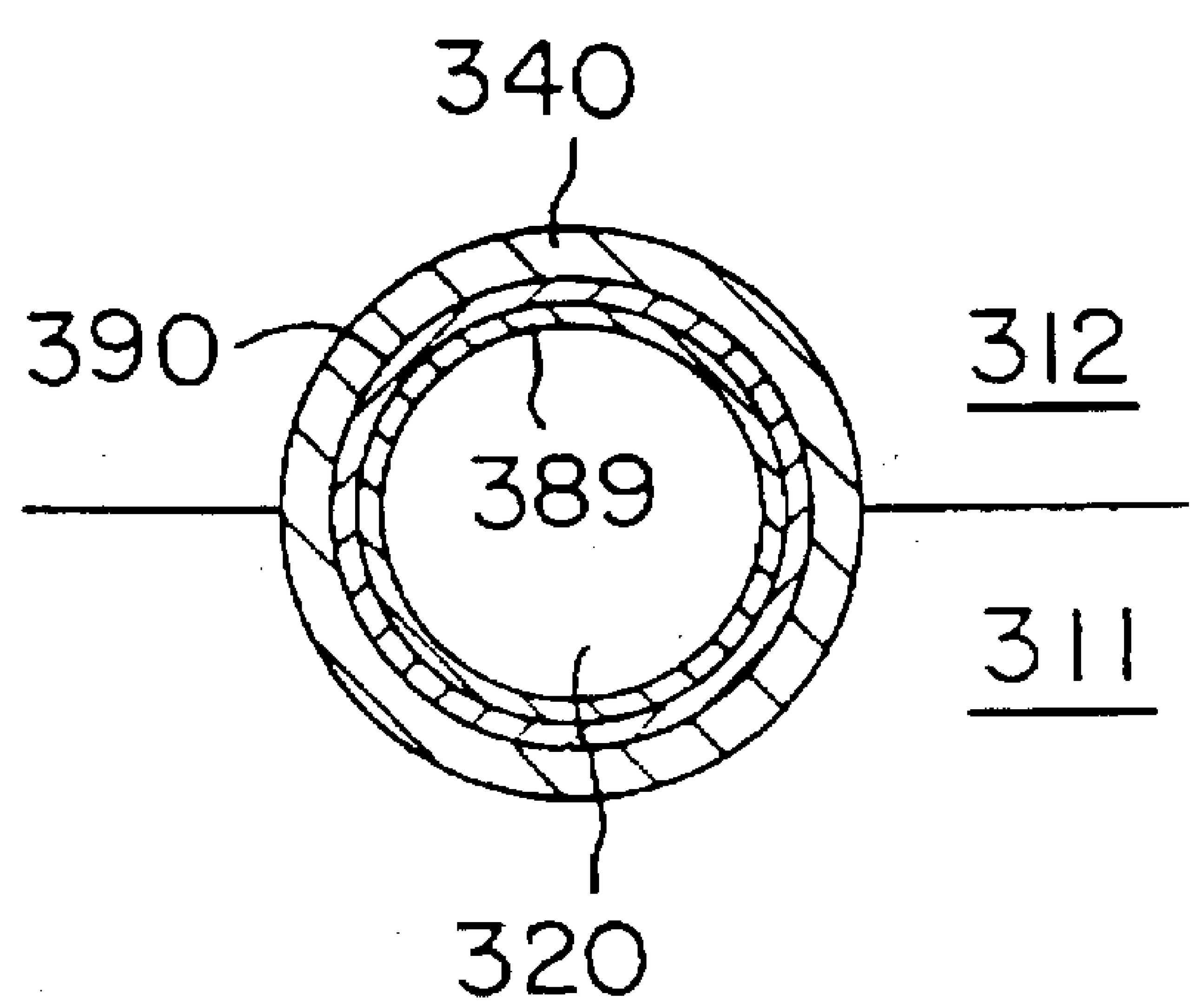


FIG. 40B

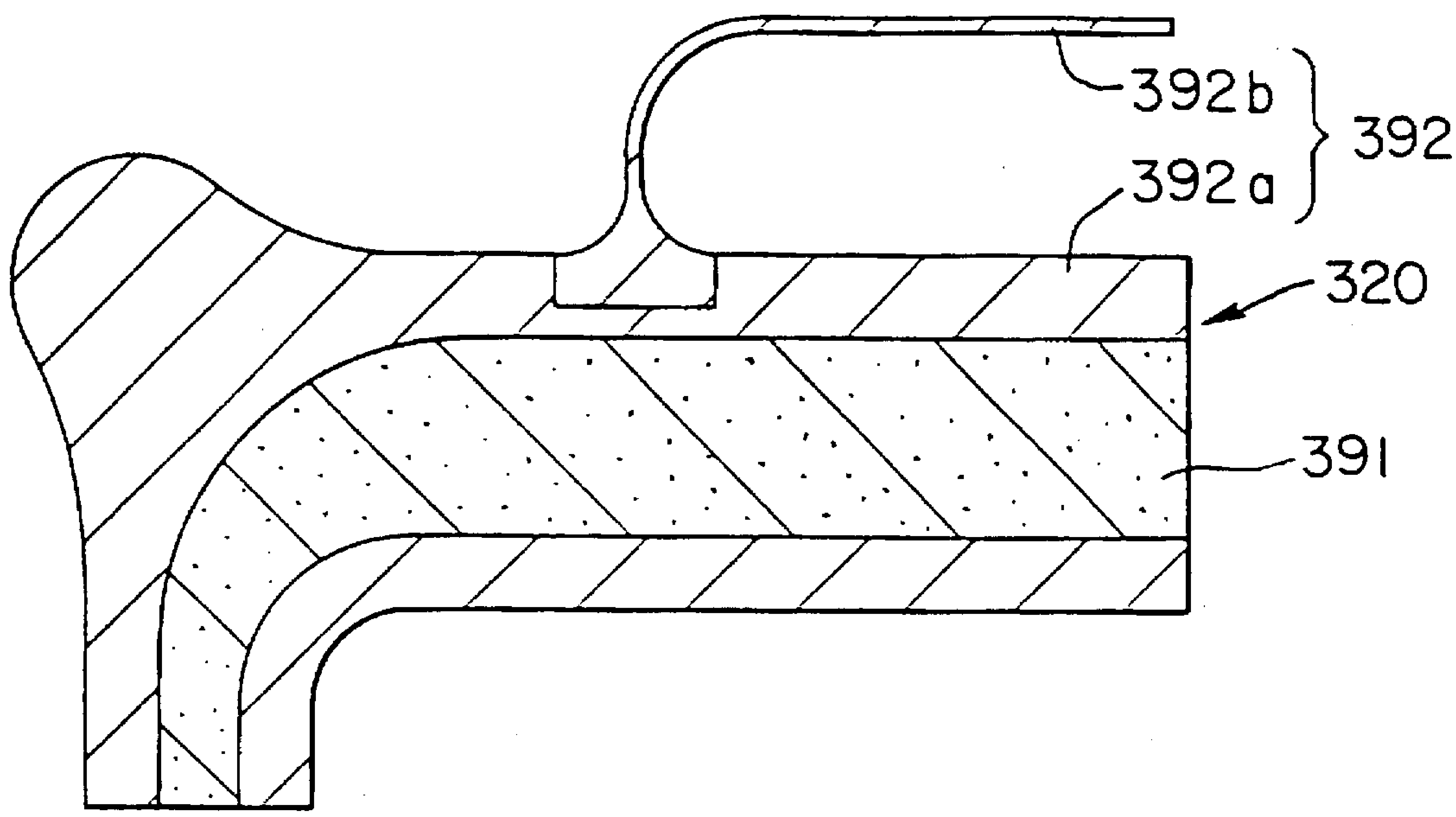


FIG. 41 A

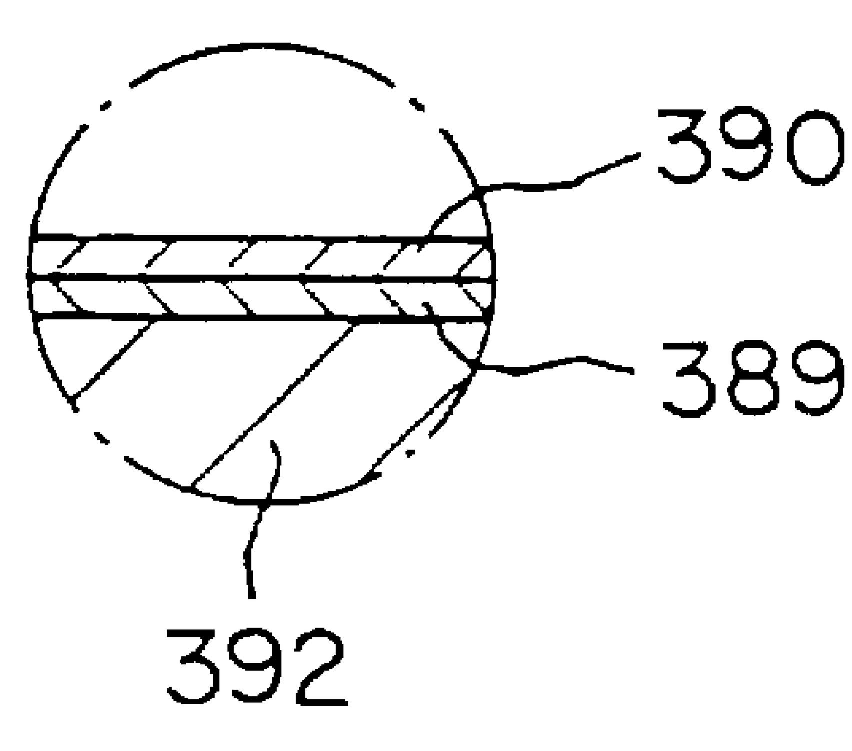


FIG. 41 B

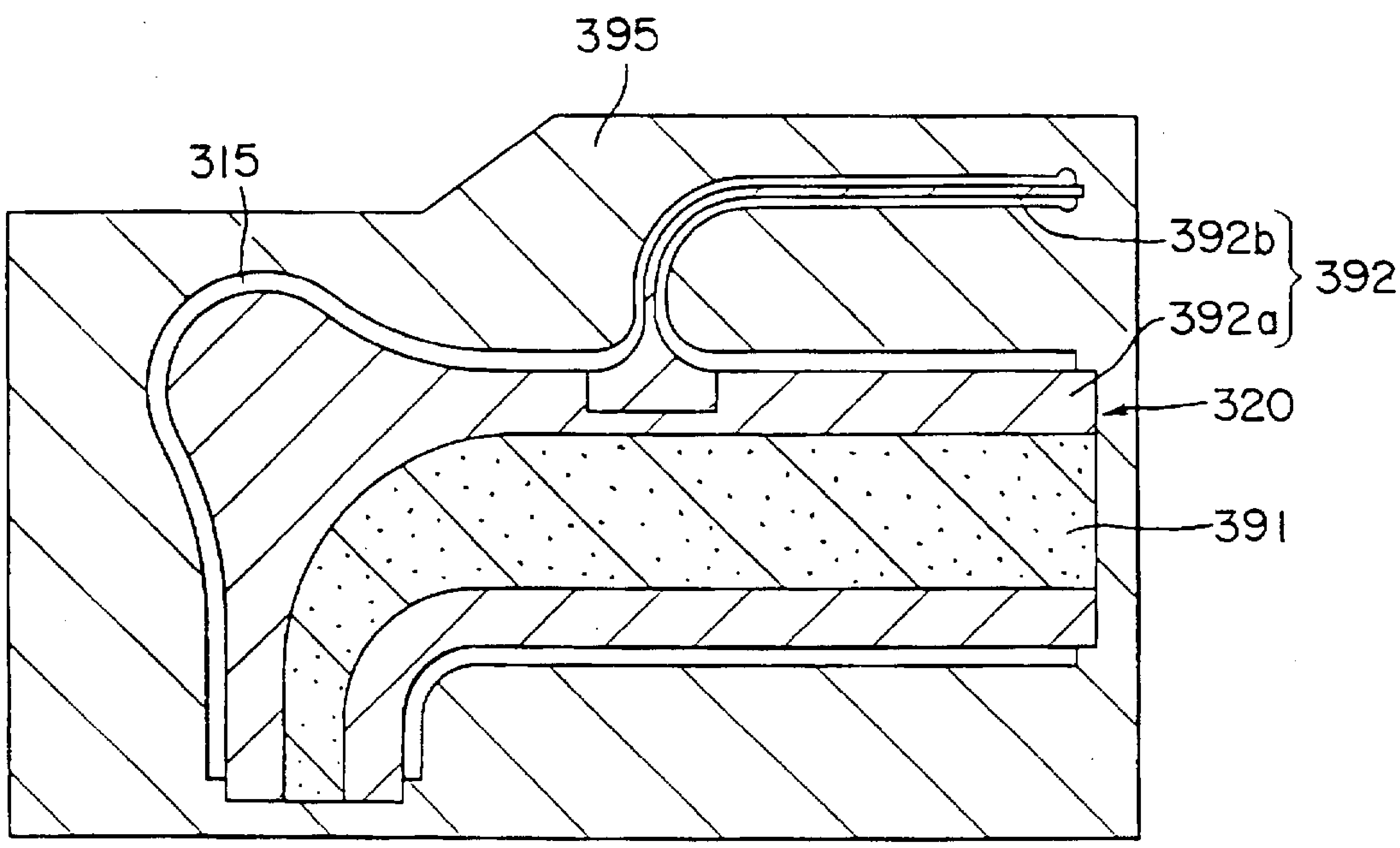


FIG. 42

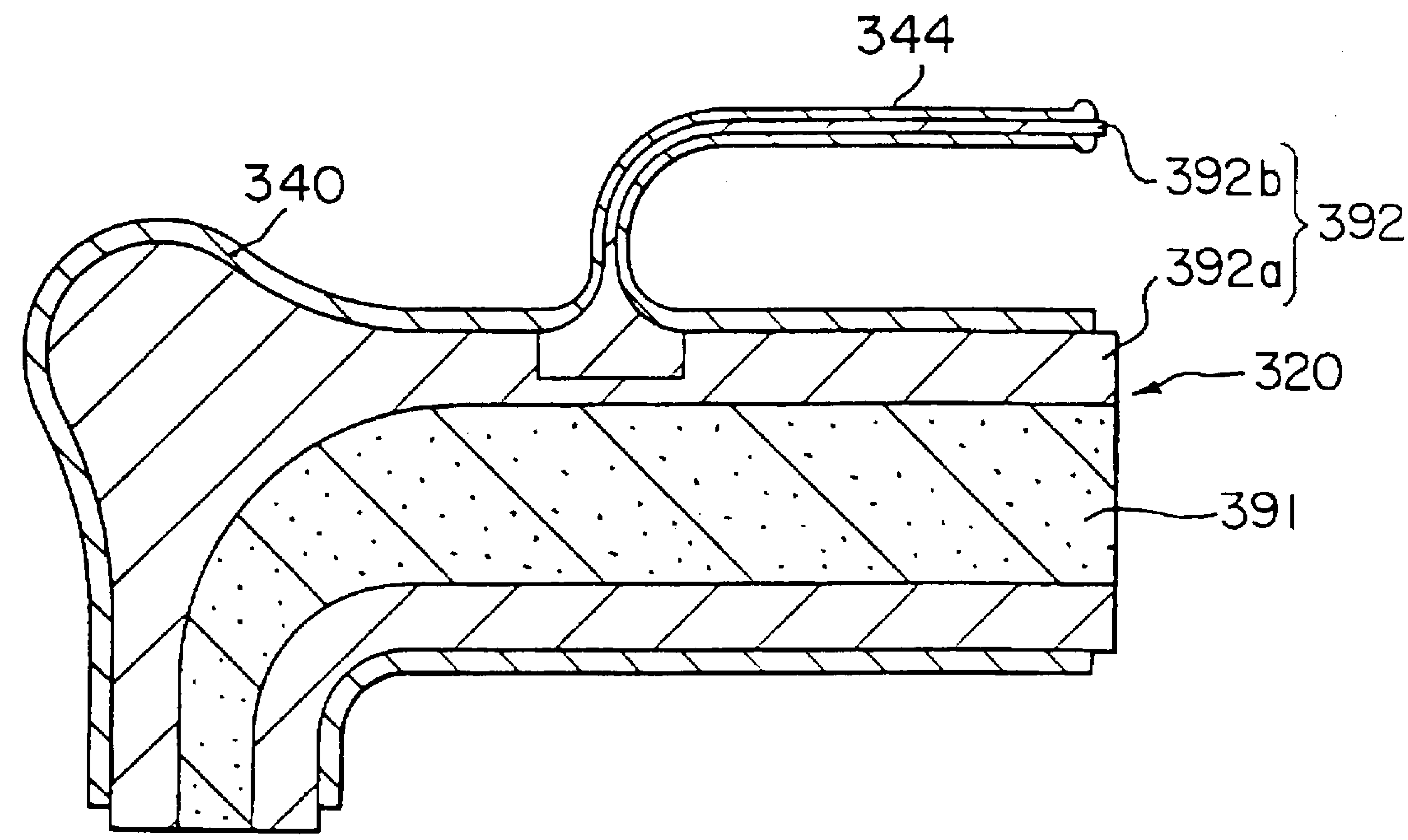


FIG. 43A

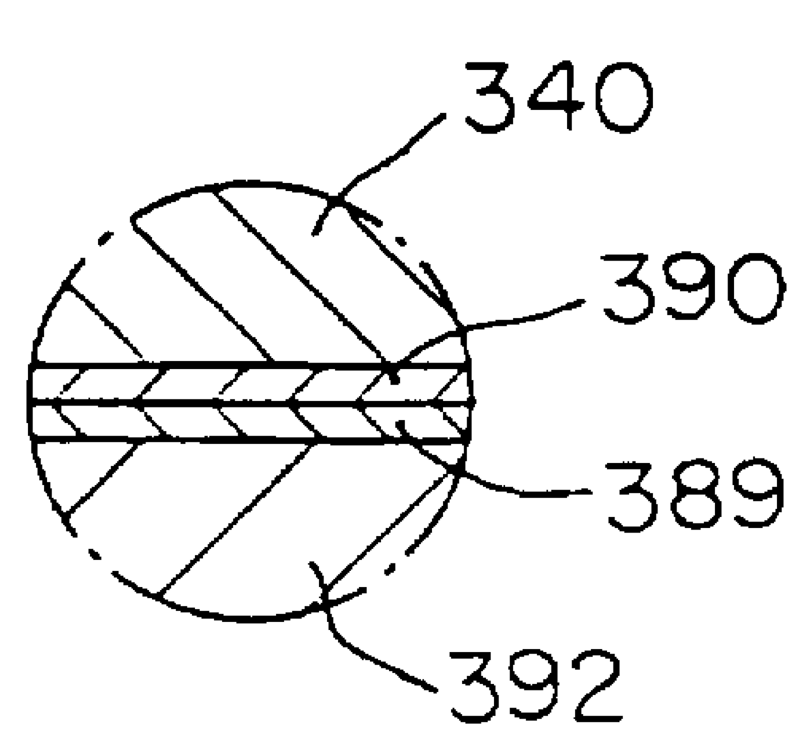


FIG. 43B

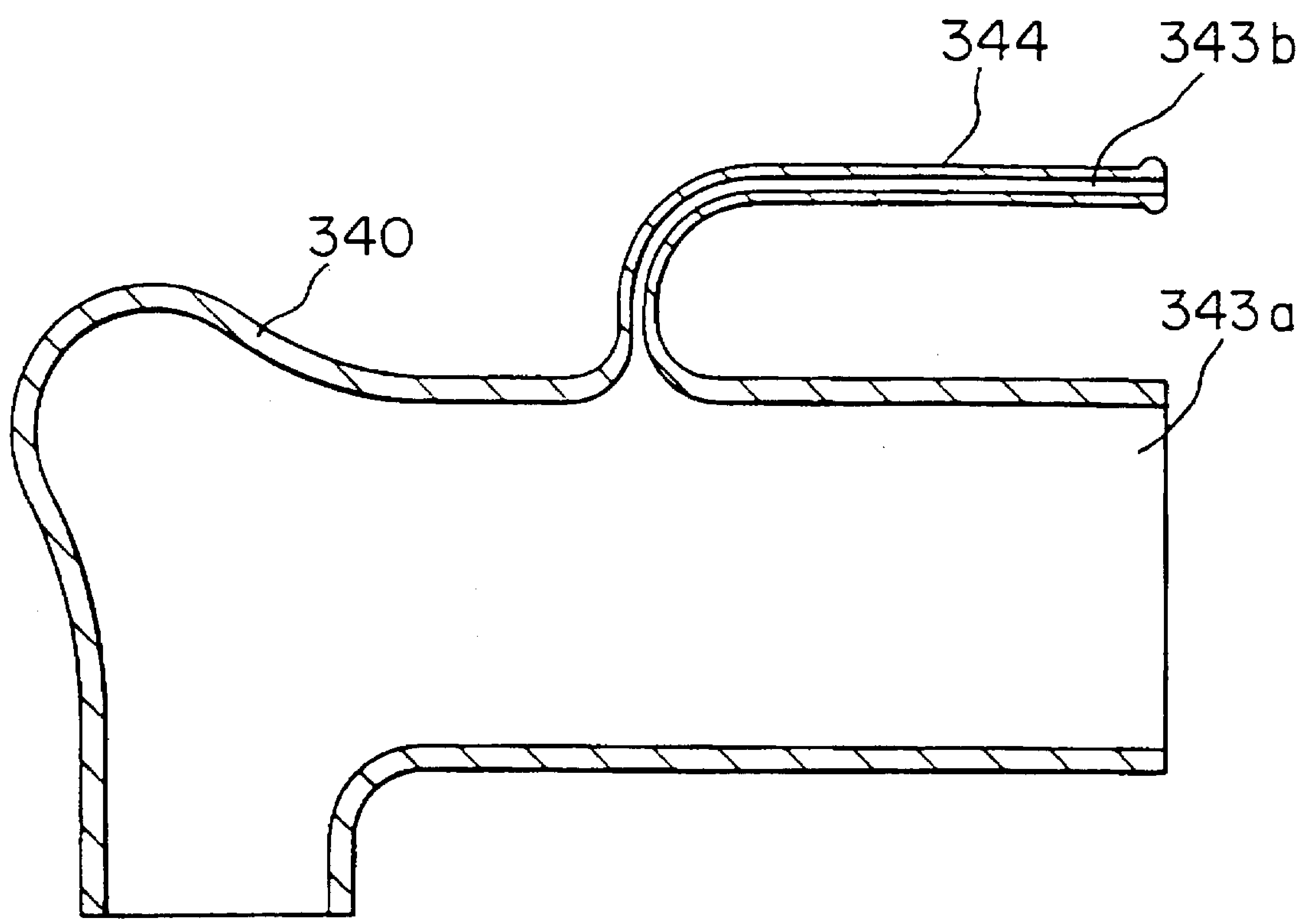


FIG. 44

CASTING METHOD USING A FORMING DIE

BACKGROUND OF THE INVENTION

The present invention relates to a forming die, a casting method using the forming die, a core, and a casting method using the core.

In a general procedure for producing an aluminum cast product using the diecasting method or the like, molten aluminum is poured into a die, and in this case the shape of the outer surface of the aluminum cast product is formed by the inner surface of a cavity of the die. When the shape of the outer surface of the aluminum cast product is flat or simple, the shape of the outer surface of the aluminum cast product can be easily formed by the inner surface of the cavity of the die.

When the outer surface of the aluminum cast product has a predetermined shape, the shape of the inner surface of the cavity is formed so as to match with a contour of the cast product.

For such cases that the outer surface of the aluminum cast product was desired to be finished in a more complicated shape, a conventional practice was such that after the aluminum cast product was once cast by a die, the outer surface of the aluminum cast product was finished in a desired shape of outer surface by grinding or cutting.

With the grinding or cutting for the aluminum cast product, the working efficiency, however, drops because of an increase of steps thereof. Further, there are cases that a desired shape of outer surface cannot be achieved even by grinding or cutting.

On the other hand, the shape of the inner surface of aluminum is formed by a core. A sand core is generally used as the core, but handling of the sand core is complicated and troublesome.

SUMMARY OF THE INVENTION

The present invention has been accomplished taking the above points into account, and an object of the invention is to provide a forming die, and a casing method using the forming die, a core, and a casting method using the core, by which a cast product having a desired shape of outer surface can be easily and simply cast without applying grinding or cutting, and by which a cast product having a desired shape of inner surface can be easily and simply cast.

A first feature of the present invention is a forming die for formation of outer surface, which is mounted on at least a part of an inner surface of a cavity of a casting die and which forms an outer surface of a cast product cast by the casting die.

A second feature of the present invention is a combination of a forming die with a die, comprising: a casting die having a cavity; and a forming die for formation of outer surface, which is mounted on at least a part of an inner surface of the cavity of the casting die and which forms an outer surface of a cast product cast by the casting die.

A third feature of the present invention is a casting method using a forming die for formation of outer surface, comprising: a step of setting the forming die for formation of outer surface, which forms an outer surface of a cast product, on an inner surface of a cavity of a casting die; a step of pouring a molten metal into the cavity of the casting die to form the cast product; and a step of taking the cast product and the forming die out of the die.

A fourth feature of the present invention is a cast product comprising a case body in which an inner space is formed opening one side thereof, and a lot of outwardly projecting portions projecting outwardly on side surfaces of the case body.

A fifth feature of the present invention is a casting method using a forming die for formation of outer surface, comprising: a step of setting the forming die for formation of outer surface containing an organic material, on an inner surface of a cavity of a casting die; a step of pouring a molten metal into the cavity of the casting die to form a cast product; a step of taking the cast product and the forming die out of the die; and a step of subjecting the cast product and the forming die to a salt bath treatment in a molten salt to decompose the organic material in the forming die into sludge of inorganic materials, and gas.

A sixth feature of the present invention is a core, which is mounted in a cavity of a casting die and which forms an inner surface of a cast product cast by the casting die, and the core is made of a thermosetting resin.

A seventh feature of the present invention is a core, which is mounted on a cavity of a casting die and which forms an inner surface of a cast product cast by the casting die, and the core is made of a thermoplastic resin.

An eighth feature of the present invention is a core, which is mounted in a cavity of a casting die and which forms an inner surface of a cast product cast by the casting die, and the core is made of a heat-resistant inorganic material bound with an adhesive organic material.

A ninth feature of the present invention is a core, which is mounted in a cavity of a casting die and which forms an inner surface of a cast product cast by the casting die, and the core is hollow as opening one side thereof.

A tenth feature of the present invention is a core, which is mounted in a cavity of a casting die and which forms an inner surface of a cast product cast by the casting die, and a surface of the core is coated with copper plating and a solder coating is formed on the copper plating.

An eleventh feature of the present invention is a casting method using a core, comprising: a step of setting a forming die for formation of outer surface containing an organic material and a core containing an organic material, in a cavity of a casting die; a step of pouring a molten metal into the cavity of the casting die to form a cast product; a step of taking the cast product, the forming die, and the core out of the casting die; and a step of subjecting the cast product, the forming die, and the core to a salt bath treatment in a molten salt to decompose the organic materials in the forming die and the core into sludge of inorganic materials, and gas.

A twelfth feature of the present invention is a casting method using a core, comprising: a step of setting a core containing an organic material, in a cavity of a casting die; a step of pouring a molten metal into the cavity of the casting die to form a cast product; a step of taking the cast product and the core out of the die; and a step of subjecting the cast product and the core to a salt bath treatment in a molten salt to decompose the organic material in the core to sludge of inorganic materials, and gas.

A thirteenth feature of the present invention is a hollow piston for an aluminum internal combustion engine, which comprises a top wall, and a side wall opening one side thereof and having a space inside thereof, and which has a circular metal plate buried in the top wall.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a perspective view to show a forming die in a shape of an outer surface in the first embodiment of the present invention.

FIG. 2 is a sectional side view of a moving die and a stationary die to show a state in which the forming die is set in a cavity.

FIG. 3A is a front view to show the moving die and stationary die.

FIG. 3B is a front view to show the stationary die.

FIG. 4 is an enlarged sectional view along the direction of line A in FIG. 2.

FIG. 5 is an enlarged sectional side view as seen in the same direction as in FIG. 2 to show the inside of the cavity in the moving die.

FIG. 6 is a perspective view to show an aluminum cast product.

FIG. 7 is a drawing to show a method for producing a plastic pellet material containing graphite in the second embodiment of the present invention.

FIG. 8 is a detail drawing to show an extruder.

FIG. 9 is a drawing to show a method for producing the forming die.

FIG. 10 is a drawing to show a state in which the forming die is being removed from the aluminum cast product.

FIG. 11 is a drawing to show a state in which the forming die is set in the cavity of the moving die in the second embodiment of the present invention.

FIG. 12 is a drawing to show a state in which the moving die is in close contact with the stationary die.

FIG. 13 is a drawing to show a state in which a molten metal is filled in the cavity of the moving die.

FIG. 14 is a drawing to show a cast product in which a steel ring is fit.

FIG. 15 is a drawing to show treatment steps for removing the forming die from the cast product.

FIG. 16 is a perspective view to show a state in which the core for casting of the shape of the inner surface is set in the stationary die and the moving die.

FIG. 17 is a sectional side view of the moving die and the stationary die to show a state in which the casting core is set therein.

FIG. 18 is a perspective view to show a state in which an aluminum cast product is immersed in a solvent.

FIG. 19 is a drawing to show a state in which the moving die is in close contact with the stationary die in the casting method using a plastic core, in the fifth embodiment of the present invention.

FIG. 20 is a drawing to show a state in which a molten metal is filled in the cavity of the moving die.

FIG. 21 is a sectional view of the core, in which a metal molded article is preliminarily buried.

FIG. 22 is a perspective view of the core, in which a metal molded article is preliminarily buried.

FIGS. 23A, 23B, and 23C are drawings to show producing steps of the metal molded article.

FIG. 24 is a drawing to show a cast product provided with the metal molded article.

FIG. 25 is a drawing to show treating steps for removing the forming die from the cast product.

FIG. 26 is a drawing to show the stationary die and the moving die in the sixth embodiment of the present invention.

FIG. 27 is a sectional view to show a state in which the core is set in the stationary die.

FIG. 28 is a sectional view to show a state in which the moving die is in close contact with the stationary die.

FIG. 29 is a sectional view to show a state in which split dies of the moving die are in close contact with each other.

FIGS. 30A and 30B are drawings to show a state in which a molten metal is filled in the cavity of the moving die.

FIG. 31 is a sectional view to show a state in which the moving die is separated from the stationary die.

FIG. 32 is a sectional view to show a state in which the split dies of the moving die are separated from each other.

FIG. 33 is a sectional view to show the aluminum cast product in which the core is incorporated.

FIG. 34 is a sectional view to show the aluminum cast product provided with a copper molded article.

FIG. 35 is a perspective view to show the moving die.

FIGS. 36A, 36B, and 36C are drawings to show producing steps of the copper molded article.

FIG. 37 is a sectional view to show the core in which the copper molded article is preliminarily buried

FIG. 38 is a perspective view to show the core in which the copper molded article is preliminarily buried.

FIGS. 39A and 39B are drawings to show treating steps for removing the forming die from the cast product.

FIGS. 40A and 40B are drawings to show a modification of the core and the casting method using the core according to the present invention.

FIGS. 41A and 41B are drawings to show another modification of the core and the casting method using the core according to the present invention.

FIG. 42 is a sectional view to show a state in which the core is set in the casting die.

FIGS. 43A and 43B are sectional views to show the core and the cast product.

FIG. 44 is a sectional view to show the aluminum cast product.

DETAILED DESCRIPTION OF THE INVENTION

First Embodiment

A first embodiment of the present invention is described below referring to the drawings. FIG. 1 to FIG. 6 are drawings to show the first embodiment of the present invention.

First, an aluminum diecast casting apparatus is schematically described referring to FIG. 2 and FIGS. 3A and 3B. As shown in FIG. 2 and FIGS. 3A and 3B, the aluminum diecast casting apparatus is provided with a stationary die **11** and a moving die **12** arranged as movable relative to the stationary die **11**, and a cavity **15** is formed in the moving die **12**. Also, the stationary die **11** is arranged so as to hermetically seal the cavity **15** in the moving die **12**, and, further, a recess **17** is formed in a surface on the moving die **12** side, of the stationary die **11**. This recess **17** communicates with a gate **18**, and, further, the gate **18** communicates with a guide path **18***a* having an input port **19** for molten aluminum.

Inside the cavity **15** in the moving die **12**, a metal core **13** projects from the moving die **12**, and this metal core **13** forms a space **43** in an aluminum cast product **40** as detailed later (FIG. 6). Here, the stationary die **11**, moving die **12**, and metal core **13** all are made of steel.

As shown in FIG. 3A and FIG. 3B, the cavity **15** in the moving die **12** is square when observed from the side of stationary die **11**, and the forming die **20** for formation of outer surface, which forms the outer surface of aluminum cast product **40**, is fit into the square cavity **15**. In this case, the forming die **20** is formed in a shape of a square barrel corresponding to the square shape of cavity **15**, and four side surfaces **20***a* of the forming die **20** become mount surfaces to come into contact with four side surfaces **15***a* of the cavity **15**. FIG. 3A is a drawing of the moving die **12** as observed from the side of stationary die **11**, while FIG. 3B a drawing of the stationary die **11** as observed from the side of moving die **12**.

As shown in FIG. 3A, the square-barrel forming die **20** is composed of four parts connected to each other on joint surfaces **29**.

The forming die **20** for formation of outer surface is next described referring to FIG. 1, FIG. 4, and FIG. 5. As shown in FIG..1, FIG. 4, and FIG. 5, the forming die **20** is shaped in a square barrel and is wholly made of a plastic, for example a polycarbonate.

The forming die **20** consists of a forming die body **21**, and the forming die body **21** has mount surfaces **25** to contact the side surfaces **15***a* of cavity **15**, and inner side surfaces **26** facing inside the cavity **15**. Also, the forming die body **21** is provided with a plurality of through holes penetrating between the mount surfaces **25** and the inner side surfaces **26**. Among them, the inner side surfaces **26** of the forming die body **21** form the outer surface of a case body **41** of the aluminum cast product **40** (FIG. 6), and the through holes **22** form outwardly projecting portions **45** in the aluminum cast product **40**.

Further, there are grooves **23** and meeting grooves **24** formed on the mount surfaces **25** of the forming die body **21**. Among them, the grooves **Z3** extend in parallel with the center axis L of the square-barrel forming die **20**, while the meeting grooves **24** extend perpendicular to the grooves **23**. The through holes **22** penetrating the forming die body **21** are arranged in a checkerboard array in length and width in the forming die body **21**, and the through holes **22** communicate with the grooves **23** provided on the mount surfaces **25** of the forming die body **21**. In detail, the grooves **23** are provided every row of through holes **22**, and the meeting grooves **24** extend perpendicular to the grooves **23** nearly in the central portion of the mount surfaces **25** of the forming die body **21**.

In this arrangement, molten aluminum passes from inside the cavity **15** through the through holes **22** in the forming die **20** to first flow into the respective grooves **23** and thereafter to meet each other at the meeting grooves **24**, then flowing into air traps **27** provided at the corners of the forming die **20**. There are eight air traps **27** in total in the entire forming die **20**, one each for either corner of one mount surface **25**, which function to receive gas such as air inside the cavity **15** during casting. Reinforcement plates **30** for reinforcing the forming die **20** are provided at the air traps **27**. Since the aluminum cast product **40** inside the air traps **27** has a lot of porosities, corresponding portions are removed after casting of the product **40**.

Next described is a casting method using the forming die for formation of outer surface, constructed in the above structure.

First, as shown in FIG. 2, the plastic, square-barrel, forming die **20** is set in the cavity **15** in the moving die **12**. In this case, the center axis L of the forming die **20** is coincident with the center axis of the metal core **13**.

Next, the moving die **12** is moved toward the stationary die **11** before the cavity **15** of the moving die **12** is hermetically closed by the stationary die **11**. In this sate, molten aluminum is put through the input port **19** into the guide path **18***a*, so that molten aluminum is injected from the guide path **18***a* through the gate **18** into the cavity **15**. Molten aluminum flowing from the gate **18** into the cavity **15** is injected in a spray form, and the temperature is about 600° C.

As shown in FIG. 4 and FIG. 5, molten aluminum flowing from the gate **18** into the cavity **15** hits the metal core **13** then to flow toward the forming die **20**. In the forming die **20** molten aluminum passes through the through holes from the inner side surface **26** side of the forming die body **21** toward the mount surface **25** side of the forming die body **21** so as to hit the side surfaces **15***a* of the cavityn **15** (the moving die **12**). After that, molten aluminum passes inside the grooves **23** extending in parallel with the center axis L of the forming die **20** on the mount surfaces **25** and then enters the meeting grooves **24** extending perpendicular to the grooves **23**. Molten aluminum is gathered by the meeting grooves **24** to flow through the meeting grooves **24** into the eight air traps **27** provided in the forming die **20**.

During the flow of the molten aluminum, the gas such as air inside the cavity **15** is pushed by molten aluminum from the through holes **22** into the grooves **23** and then flows from the grooves **23** through the meeting grooves **24** into the air traps **27**.

Next, molten aluminum filled in the cavity **15** is rapidly cooled by the stationary die **11** and moving die **12** to form the aluminum cast product **40**.

In this case, heat transfer occurs also from molten aluminum to the polycarbonate forming die **20**. However, because the thermal conductivity of polycarbonate forming die **20** is normally far smaller than that of the steel stationary die **11** and moving die **12** (for example, the thermal conductivity of polycarbonate is 4.6×10^{-4} cal/s° cm°C. while the thermal conductivity of iron is 0.18 cal/scm° cm°C.), an amount of heat transfer from molten aluminum to the forming die **20** becomes extremely small. Thus, the polycarbonate forming die **20** is not melted during casting, and the aluminum cast product **40** excellent in accuracy of shape can be formed accordingly.

The forming die **20** will not be melted even with slow escape of heat from a thick portion of the aluminum product, if the surface of the forming die **20** corresponding to the thick portion of aluminum cast product **40** is coated with very-high-temperature-resistant silicone rubber not shown.

Next, the moving die **12** is separated from the stationary die **11**, and the aluminum cast product **40** and forming die **20** are taken together out of the cavity **15** formed in the moving die **12**.

As shown in FIG. 6, the aluminum product **40** is immersed together with the forming die **20** in a solvent **51** in a container **50**. In FIG. 6, the aluminum product **40** is shown without the forming die **20** for convenience sake. Immersing the aluminum cast product **40** and forming die **20** in the solvent **51** as described, the polycarbonate forming die **20** can be dissolved in the solvent **51** to be removed. Also, setting a supersonic generator **60** in the solvent **51** in the container **50**, supersonic waves can be generated in the solvent **51**, whereby the forming die **20** can be dissolved and removed more quickly.

The solvent for dissolving to remove the polycarbonate forming die **20** is one selected from the following hydrocarbon solvents.

Methylene chloride (dichloromethane or methylene chloride), NMP (N-methyl-2-olefin), DMP (NN-dimethylformamide), MFK (methyl ethyl ketone), ethyl acetate (ester).

As shown in FIG. 6, the aluminum cast product **40** is used as a heat radiation case in which an electric component or the like (not shown) is set and which radiates heat generated by the electric component to the outside, but it can also be used for other purposes. The aluminum cast product **40** has the case body **41** inside which the space **43** is formed opening at one side **43***a*, and a lot of outwardly projecting portions **45** project outwardly from the case body **41** on four side surfaces of the case body **41**. A projection **42** slightly projecting to the outside is provided on the bottom of the case body **41**.

Among them, the space **43** in the case body **41** is formed by the metal core **13**, while the outer surface of the case body **41** (the base surface of the outwardly projecting portions **45**) is formed by the inner side surfaces **26** of the forming die **20**. Also, a lot of outwardly projecting portions **45** projecting from the case body **41** are formed by the through holes **22** in the forming die **20**, and further, the projection **42** on the bottom portion of the case body **41** is formed by the recess **17** in the stationary die **11**.

Further, the outwardly projecting portions **45** are connected to each other at distal ends thereof by connection plates **46**, and the connection plates **46** are formed by the grooves **23** and meeting grooves **24** in the forming die **20**.

After that, the connection plates **46** may be ground with necessity, and by grinding the connection plates **46**, cast parts in the connection plates **46** and air traps **27** can be removed. In another case, where the connection plates **46** are not ground, the outwardly projecting portions **45** are reinforced by the connection plates **46** with regard to the strength. Even in the case where the connection plates **46** are not ground, the cast parts in the air traps **27** are removed because there are porosities therein.

According to the present embodiment as described, the forming die **20** can be dissolved and removed from the aluminum cast product **40** simply by immersing the aluminum cast product **40** together with the forming die **20** into the solvent **51** after casting of the aluminum cast product **40** using the polycarbonate forming die **20**. Thus, the aluminum cast product **40** can be easily and simply obtained in a complicated shape of outer surface having a lot of outwardly projecting portions **45** on the four side surfaces of case body **41**, without grinding or cutting.

A modification of the present invention is next described. The above embodiment showed the forming die **20** shaped in the square barrel in contact with the four side surfaces of cavity **15**, but without a need to be limited to this, a quarter of the square-barrel forming die split on the borders of joint surfaces **29** may be used mounting it only on one side surface of cavity **15**. In this case, the forming die **20** is mounted through one mount surface on the one side surface of cavity **15**.

Also, the embodiment showed an example in which the polycarbonate forming die **20** was dissolved and removed from the aluminum cast product **40** with the solvent **51**, but without a need to be limited to this, it can be removed from the aluminum cast product **40** after the aluminum cast product **40** and forming die **20** are heated together up to about 280° to 350° C. to bring the entire forming die **20** into a semi-molten state. Since polycarbonate has the softening point of about 160° C. and the melting point of 380° to **400°** C., the forming die **20** becomes semi-melted by heating the forming die **20** and the aluminum cast product **40** together up to 280° to 350° C., whereby the forming die **20** can be easily removed from the aluminum cast product **40**. It is also possible that after the forming die **20** is removed in the semi-molten state, the forming die **20** is further removed by the solvent **51** for perfect removal.

In another arrangement, as shown in FIG. **10**, the forming die **20** can be peeled off from the aluminum cast product **40** by shot blast. In this case, a shot blast apparatus **61** is set close to the aluminum cast product **40** and forming die **20** and then a lot of shots are ejected (blasted) onto the outer surface of the aluminum cast product **40**. Then the polycarbonate forming die **20** is peeled off by the thus ejected shots to be removed.

During the shot blast operation with the shot blast apparatus, the aluminum cast product **40** may be heated up to about 200° C., whereby the peeling-off removal of the forming die **40** becomes easier. The shots may be aluminum powder, glass powder, silica powder, graphite powder, salt powder, or anti-rust metal powder.

Further, the forming die **20** may be peeled off and removed from the aluminum cast product **40** by high-temperature and high-pressure steam. In this case, a steam spraying apparatus **62** is set close to the outer surface of the aluminum cast product and then high-temperature and high-pressure steam (for example steam at 300° C. to 500° C.) is sprayed through a nozzle of the steam spraying apparatus. The thus sprayed steam peels off the polycarbonate forming die **20**, thus removing it.

Furthermore, as shown in FIG. **10**, the forming die **20** may be removed from the cast product **40** in a furnace **65** as heating the aluminum cast product **40** and the forming die **20** to about 400° C. in the furnace **65** shown by the doubled-dashed chain line to melt the forming die **20** completely. In this case, the shot blast apparatus **61** and the steam spraying apparatus **62** become unnecessary in FIG. **10**.

The above embodiment showed an example in which the forming die **20** was made of polycarbonate, but without a need to be limited to it, the forming die **20** may be one which is constructed of a thermoplastic inner resin and a heat-resistant resin covering the entire surface of the inner resin.

In this case, the thermoplastic inner resin may be selected from fluororesins (polyfluoroethylene resins) such as ethylene tetrafluoride, polyimide resins, polyamideimide resins, polysulfone resins, vinyl chloride resins, polyamide resins (nylon resins), polypropylene resins, polyethylene resins, polyester resins (Tetron resins), or polysulfonic acid resins.

The heat resistant resin covering the entire surface of the inner resin may be the silicone rubber as described previously or a silicone resin.

Further, the forming die **20** may be made of a material obtained by mixing particles of a thermoplastic resin such as a polypropylene resin with particles of a heat-resistant resin such as a silicone resin and baking the mixture to harden. Also, the forming die may be made of a material obtained by mixing the polypropylene resin particles with either calcium carbonate particles, calcium sulfate particles, or calcium silicate particles and baking the mixture to harden.

Further, a biodegradable plastic may be used for the forming die **20**. Here, the biodegradable plastic means a plastic which is decomposed into low-molecular-weight compounds giving no negative effects to the environment, in nature in connection with microorganisms.

The biodegradable plastic can be classified into the complete degradation type and partial degradation type. The complete degradation type plastic may include plastics of naturally-occurring polymers consisting of a complex of starch and modified polyvinyl alcohol, starch and polycaprolactone, or chitosan and cellulose; fermentation product plastics consisting of a microorganism-produced polyester or a microorganism-derived cellulose; and synthetic plastics consisting of an aliphatic polyester. The partial degradation type plastic may include plastics of a mixture of starch in polyethylene, and alloys of polycaprolactone and a general-purpose plastic.

When the biodegradable plastic forming die is used, the forming die **20** can be readily discarded after peeled off to be removed from the aluminum cast product **40** after cast.

Also, the forming die **20** may be made of paper. The paper forming die **20** may be obtained by pressurizing to dehydrate slurry pulp under a pressure of about 70 kg/cm^2 and thereafter drying the resultant for about 24 hours.

When the forming die **20** made of paper is used, heat transfer also occurs from molten aluminum to the forming die **20** during casting. However, because the thermal conductivity of the paper forming die **20** is generally smaller than that of the steel stationary die **11** and moving die **12**, an amount of heat transfer from aluminum melt **55** to the paper forming die **20** becomes very small. Since oxygen is rare inside the cavity **15** filled with molten aluminum, the surface of the paper forming die **20** is slightly burnt during casting to be carbonized, but the forming die **20** will never be burnt, thus forming the aluminum cast product **40** excellent in accuracy of shape. Also, the insulation effect of the paper forming die **20** can prevent sudden temperature drop of aluminum, thereby preventing a strain from being caused by the temperature drop in the aluminum cast product **40**. After cast, the paper forming die **20** can be burnt up to remove by heating the aluminum cast product **40** and paper forming die **20**.

Furthermore, a die made of a rubber may be used as the forming die **20** in addition to the plastic one. Namely, the entire forming die **20** may be made of a rubber material.

The rubber material generally includes a natural rubber, a styrene butadiene rubber, a polyisoprene rubber, a polybutadiene rubber, a polyethylene-propyrene rubber, butyl rubber, neoprene, a acrylonitrile-butadiene rubber, or a polysulfide rubber. The entire forming die **20** is preferably made of a heat-resistant silicone rubber. The forming die made of the rubber material may be removed from the cast product **40** by heating to bring it into a molten state after casting, or it may be removed from the cast product **40** by dissolving it with a solvent. Further, the forming die **20** produced of the rubber material may be removed from the cast product **40** by shot blast treatment, or it may be removed from the cast product **40** by spraying high-temperature and high-pressure steam.

In the above embodiment the aluminum diecasting method was described as a diecasting method, but the present invention can be applied to any other diecasting method, such as the gravity diecasting method, the low pressure diecasting method, and the precision diecasting method. Further, the cast product may be not only of aluminum, but also of lead, zinc, magnesium, manganese or an alloy thereof.

As described above, according to the present invention, the cast product having a complicated shape of outer surface can be readily and simply obtained just by, after producing the cast product using the forming die, taking out the cast product and the forming die from the casting die and thereafter removing the forming die from the cast product. In this case, because the shape of the outer surface of the cast product is formed by the forming die, grinding or cutting etc. does not have to be employed for forming the complicated shape of outer surface.

Second Embodiment

A second embodiment of the present invention is next described. In the second embodiment, the forming die **20** is made of powder graphite and a plastic material, for example a polycarbonate material, for combining powder graphite with each other, but the other parts are substantially the same as those in the first embodiment shown in FIG. **1** to FIG. **6** and FIG. **10**.

A method for producing such a forming die **20** is first described. The forming die **20** is produced by injection molding using a graphite-added plastic pellet material. First, production procedures of the graphite-added plastic pellet material will be described schematically.

As shown in FIG. **8**, a raw material **125** consisting of polycarbonate pellets and powder graphite is put into a hopper **123** in an extruder **110**. A weight ratio between the polycarbonate pellets and powder graphite in the hopper **123** is in the range of 90:10 to 10:90 corresponding to a weight ratio of a polycarbonate component and a graphite component in a graphite-added plastic pellet material **117** as described below. Next, the raw material **125** in the hopper **123** is fed to a cylinder **126**, and the raw material **125** is pressurized in the cylinder **126** with rotation of a screw **128** and heated by a heater **127**.

When the raw material **125** is heated and compressed in the cylinder **126**, the polycarbonate pellets melt to be mixed with powder graphite and the mixture flows out through a die **111** (FIG. **7**) from a head **129** of the extruder **110**.

Since graphite does not chemically react with synthetic resins under environmental conditions below 1000° C., the polycarbonate and graphite exist independently of each other while keeping respective specific properties in the mixture of polycarbonate and graphite.

Next, the polycarbonate and graphite mixed in the extruder **110**, as shown in FIG. **7**, is fed from the die **111** to a pelletizer **116** forming a strand mixture **112**. In the pelletizer **116** the strand mixture **112** is fed by feed rollers **113**, **114** to a rotary knife **115**, and the mixture is finely broken by the rotary knife **115** to obtain the graphite-added plastic pellet material **117** with a diameter of 1 to 2 mm.

This graphite-added plastic pellet material **117** is a mixture of the polycarbonate component and graphite component, and the weight ratio between the polycarbonate component and graphite component is in the range of 90:10 to 10:90 as described previously. If the weight ratio between the polycarbonate component and graphite component is greater than 90:10 with regard to the polycarbonate component, the releasability becomes poor for products obtained by injection molding.

If the graphite component is more than 10:90 in the weight ratio between the polycarbonate component and graphite component, the toughness becomes poor for products obtained by injection molding.

Incidentally, the combination of the polycarbonate component with the graphite component is determined as follows. If injection-molded articles are formed in a simple structure and a large volume, a combination of the polycarbonate component and graphite component is selected in the range where the volume % of graphite is relatively large, from the following table. In this case, for example, supposing a combination with the volume % of graphite being 70% is selected, 1540 g of graphite and 360 g of polycarbonate are mixed with each other. The following table shows formulations (g) of graphite and polycarbonate corresponding to each volume % of graphite when the total volume is 1000 cm^3.

On the other hand, if injection-molded articles are formed in a complex structure and a small volume, a combination between the polycarbonate component and graphite component is selected in the range where the volume % of graphite is relatively small.

TABLE 1

Formulation of Graphite and Polycarbonate

Vol % of Graphite	Graphite (g)	Resin (g)
0	0.0	1200.0
1	22.0	1188.0
2	44.0	1176.0
3	66.0	1164.0
4	88.0	1152.0
5	110.0	1140.0
6	132.0	1128.0
7	154.0	1116.0
8	176.0	1104.0
9	198.0	1092.0
10	220.0	1080.0
11	242.0	1068.0
12	264.0	1056.0
13	286.0	1044.0
14	308.0	1032.0
15	330.0	1020.0
16	352.0	1008.0
17	374.0	996.0
18	396.0	984.0
19	418.0	972.0
20	440.0	960.0
21	462.0	948.0
22	484.0	936.0
23	506.0	924.0
24	528.0	912.0
25	550.0	900.0
26	572.0	888.0
27	594.0	676.0
28	616.0	864.0
29	638.0	852.0
30	660.0	840.0
31	682.0	828.0
32	704.0	816.0
33	726.0	804.0
34	748.0	792.0
35	770.0	780.0
36	792.0	768.0
37	814.0	756.0
38	836.0	744.0
39	858.0	732.0
40	880.0	720.0
41	902.0	708.0
42	924.0	696.0
43	946.0	684.0
44	968.0	672.0
45	990.0	660.0
46	1012.0	648.0
47	1034.0	636.0
48	1056.0	624.0
49	1078.0	612.0
50	1100.0	600.0
51	1122.0	588.0
52	1144.0	576.0
53	1166.0	564.0
54	1188.0	552.0
55	1210.0	540.0
56	1232.0	528.0
57	1254.0	516.0
58	1276.0	504.0
59	1298.0	492.0
60	1320.0	480.0
61	1342.0	468.0
62	1364.0	456.0
63	1386.0	444.0
64	1408.0	432.0
65	1430.0	420.0
66	1452.0	408.0
67	1474.0	396.0
68	1496.0	384.0
69	1518.0	372.0
70	1540.0	360.0
71	1562.0	348.0
72	1584.0	336.0
73	1606.0	324.0
74	1628.0	312.0
75	1650.0	30.0
76	1672.0	288.0
77	1694.0	276.0
78	1716.0	264.0
79	1738.0	252.0
80	1760.0	240.0
81	1782.0	228.0
82	1804.0	216.0
83	1826.0	204.0
84	1848.0	192.0
85	1870.0	180.0
86	1892.0	168.0
87	1914.0	156.0
88	1936.0	144.0
89	1958.0	132.0
90	1980.0	120.0
91	2002.0	108.0
92	2024.0	96.0
93	2046.0	84.0
94	2068.0	72.0
95	2090.0	60.0
96	2112.0	48.0
97	2134.0	36.0
98	2156.0	24.0
99	2178.0	12.0
100	220.0	0.0

Next described referring to FIG. **9** is a method for producing the forming die **20**, using the graphite-added plastic pellet material **117** thus obtained.

As shown in FIG. **9**, an injection molding machine **130** has an injection ram **135** arranged as slidable in an injection cylinder **134**, and an oil hydraulic motor **137** driving to rotate the injection ram **135** through a drive shaft **138**. A screw **132** is connected with the injection ram **135**, and the screw **132** is set in a barrel **136**. Further, the graphite-added plastic pellet material **117** is supplied from the hopper **131** to the screw **132**. A nozzle **139** is provided at the distal end of screw **132**, and the nozzle **139** is connected to an injection die composed of a stationary die **140** and a moving die **141**.

Next described is the injection molding method of the forming die. First, the graphite-added plastic pellet material **117** is put into the hopper **131**, and then the oil hydraulic motor **137** starts rotating the screw **132** through the injection ram **135**. During this time, the graphite-added plastic pellet material **117** is supplied into the screw **132**, whereby the polycarbonate component in the graphite-added plastic pellet material **117** is melted by the rotation of screw **132**. Then the mixture in which powder graphite is mixed in the melted polycarbonate is injected through the nozzle **139** into the cavity between the stationary die **140** and moving die **141**, thereby obtaining the forming die **20** made of polycarbonate and powder graphite.

Polycarbonate among the components of the forming die **20** has characteristics of excellent heat resistance and high toughness. On the other hand, powder graphite is a material of the hexagonal system and has the hardness of 1.5 and the relative density of 2.2. Graphite has excellent heat resistance and also has excellent lubricity (releasability) from the crystal structure thereof. Also, graphite has the considerable mechanical strength at high temperatures and has such a characteristic that it is soluble in neither inorganic solvents nor organic solvents.

Further, polycarbonate and graphite do not chemically react with each other as described previously, and exist with respective specific properties.

From these points, the forming die **20** made of polycarbonate and powder graphite becomes an injection-molded article excellent in heat resistance and in lubricity. In this case, out of the components of the forming die **20**, polycarbonate functions to bond powder graphite to each other.

As described, the forming die **20** made of polycarbonate and powder graphite as shown in FIG. **1** is obtained.

When the forming die **20** shown in FIG. **1** is set in the cavity **15** in the moving die **12** shown in FIG. **2** and the cavity **15** is filled with molten aluminum, molten aluminum filled in the cavity **15** is rapidly cooled by the stationary die **11** and moving die **12** to form the aluminum cast product **40**.

In this case, heat transfer occurs also from molten aluminum to the forming die **20** made of powder graphite and polycarbonate. However, because the thermal conductivity of the forming die **20** made of powder graphite and polycarbonate is far smaller than that of the steel stationary die **11** and moving die **12**, an amount of heat transfer from molten aluminum to the forming die **20** becomes extremely small. Thus, the forming die **20** made of powder graphite and polycarbonate is never melted during casting, and the aluminum cast product **40** excellent in accuracy of shape can be formed accordingly.

Next, the moving die **12** is separated from the stationary die **11**, and the aluminum cast product **40** is taken out together with the forming die **20** from the cavity **15** formed in the moving die **12**.

In this case, because the forming die **20** has excellent lubricity and releasability because of the graphite component, the forming die **20** can be easily and simply taken together with the aluminum cast product **40** out of the cavity **15**, while preventing a part of the forming die **20** from being deposited on or adhering to the inside of the cavity **15**. Accordingly, the inside of the cavity **15** does not have to be cleaned every aluminum diecasting, whereby the aluminum diecasting can be completely automatized. Next, the aluminum cast product **40** and forming die **20** are heated at about 300° C., whereby the polycarbonate component in the forming die **20** melts partially to flow out of the outer surface of the aluminum cast product **40**.

As shown in FIG. **6**, the aluminum product **40** is afterward immersed together with the forming die **20** in the solvent **51** in the container **50**. In FIG. **6**, the aluminum product **40** is shown without the forming die **20** for convenience' sake. Thus immersing the aluminum cast product **40** and forming die **20** in the solvent **51**, the remaining polycarbonate component of the forming die **20** is dissolved in the solvent **51** to be completely removed from the aluminum cast product **40**. On the other hand, because the graphite component in the forming die **20** is excellent in lubricity and releasability, the graphite component is easily and simply removed from the aluminum cast product **40** to precipitate on the bottom in the solvent **51**. Also, the polycarbonate component dissolved in the solvent **51** floats on the surface of solvent **51**.

Because of this, the graphite component precipitating on the bottom of solvent **51** can be easily and simply separated in the solvent from the dissolved polycarbonate component floating on the surface of solvent **51**, thus facilitating disposal.

Also, setting a supersonic generator **60** in the solvent **51** in the container **50**, supersonic waves can be generated in the solvent **51**, whereby the forming die **20** can be dissolved and removed more quickly.

According to the present embodiment as described, the forming die **20** can be dissolved and removed from the aluminum cast product **40** simply by immersing the aluminum cast product **40** together with the forming die **20** into the solvent **51** after casting of the aluminum cast product **40** using the forming die **20** made of powder graphite and polycarbonate. Thus, the aluminum cast product **40** can be easily and simply obtained in a complicated shape of outer surface having a lot of outwardly projecting portions **45** on the four side surfaces of case body **41**, without grinding or cutting.

A modification of the present invention is next described. The above embodiment showed an example in which the forming die **20** was the forming die **20** made of powder graphite and polycarbonate, but without a need to be limited to this, polycarbonate may be replaced by another thermoplastic resin. In this case, the thermoplastic inner resin may be selected from fluororesins (polyfluoroethylene resins) such as ethylene tetrafluoride, polyimide resins, polyamide-imide resins, polysulfone resins, vinyl chloride resins, polyamide resins (nylon resins), polypropylene resins, polyethylene resins, polyester resins (Tetron resins), or polysulfonic acid resins.

In another modification, the forming die **20** is composed of a plurality of parts, wherein portions having a thick and simple shape among the parts are arranged to include a more graphite component but a less plastic component while portions having a thin and complex shape are arranged to include a less graphite component and a more plastic component. As in this modification, when the portions having a thick and simple shape are arranged to include a lot of the graphite component, the forming die **20** can be easily removed from the aluminum cast product **40** with a smaller amount of usage of the solvent. The above embodiment showed an example in which the forming die **20** was removed by heating the aluminum cast product **40** and forming die **20** and thereafter immersing them in the solvent **51**, but the forming die **20** may be removed employing either the heating removal or the solvent removal.

The above embodiment showed an example in which the forming die **20** is composed of powder graphite and a plastic material for binding powder graphite with each other, but without a need to be limited to this, the forming die **20** may be composed of powder graphite and a rubber material for binding powder graphite with each other. The rubber material generally includes a natural rubber, a styrene butadiene rubber, a polyisoprene rubber, a polybutadiene rubber, a polyethylene-propyrene rubber, a butyl rubber, neoprene, an acrylonitrile-butadiene rubber, or a polysulfide rubber, among which a heat-resistant silicone rubber is preferably used.

In the case where the forming die **20** is made of powder graphite and the rubber material, a graphite-added rubber pellet material is first produced, and the forming die is then produced using the graphite-added rubber pellet material. The forming die **20** made of powder graphite and the rubber material may be removed from the cast product **40** by dissolving it with a solvent or by heating to bring it into a molten state, after casting.

As described above, according to the present invention, the forming die can be removed from the cast product simply by, after casting the cast product using the forming die, taking out the cast product and forming die out of the casting die and thereafter immersing the cast product and forming die in the solvent, so that even a cast product having a complex shape of outer surface can be obtained easily and simply. In this case, because the graphite component of the forming die is excellent in lubricity and releasability, the cast product and forming die can be easily taken out of the casting die. Also, simply by immersing the cast product and forming die in the solvent, the plastic component in the forming die is dissolved in the solvent while the graphite component flows into the solvent. In the solvent, graphite precipitates on the bottom while the dissolved plastic component floats on the surface of solvent, whereby they can be separated easily from each other in the solvent.

Third Embodiment

A third embodiment of the present invention is described below referring to the drawings. FIG. 11 to FIG. 15 are drawings to show the third embodiment of the present invention.

First, an aluminum diecast casting apparatus is schematically described referring to FIG. 11 to FIG. 13. As shown in FIG. 11 to FIG. 13, the aluminum diecast casting apparatus is provided with a stationary die 11 and a moving die 12 arranged as movable relative to the stationary die 11, and a cavity 15 is formed in the moving die 12. Also, the stationary die 11 is arranged so as to hermetically seal the cavity 15 in the moving die 12.

A gate 18, which communicates with the cavity 15, is formed in the stationary die and, further, a guide path 18*a* having an input port 19 for molten aluminum communicates with the gate 18.

The stationary die 11 is provided with a metal core 13 projecting into the cavity in the moving die 12, and this metal core 13 forms a space 43 in an aluminum cast product 40 as detailed later (FIG. 14). Here, the stationary die 11, moving die 12, and metal core 13 all are made of steel.

The forming die 20 for formation of outer surface, which forms an outer surface of the aluminum cast product 40, is set into the cavity 15 in the moving die 12. The cavity 15 in the moving die 12 is cylindrical when observed from the side of stationary die 11, and the forming die 20 is almost cylindrical in correspondence with the cylindrical shape of the cavity 15.

Next described is the material of the forming die 20. The forming die 20 is comprised of powder graphite and an organic material having an adhesive function to bind the powder graphite. The organic material to bind the powder graphite can be a thermosetting synthetic resin such as a phenol resin, a urea resin, a melamine resin, an unsaturated polyester resin, a silicone resin, etc. The thermosetting synthetic resin is one obtained generally by forming initial, linear polymer molecules, and further raising the temperature to form bondings between them (crosslinking). As a result, a three-dimensional (stereoscopic) network is formed to increase the molecular weight, whereby it come to have such a property that it does not soften when again heated.

Incidentally, a weight ratio between powder graphite and the thermosetting synthetic resin is in the range of 90:10 to 10:90.

In addition, a thermoplastic synthetic resin, for example, a polycarbonate may also be used as the organic material to bind powder graphite, and a natural adhesive such as starch, paste, etc. may also be used.

Powder graphite is a material of the hexagonal system and has the hardness of 1.5 and the relative density of 2.2. Graphite has excellent heat resistance and also has excellent lubricity (releasability) from the crystal structure thereof. Also, graphite has the considerable mechanical strength at high temperatures and has such a characteristic that it is soluble in neither inorganic solvents nor organic solvents.

As shown in FIG. 11, a metal material different in quality from the aluminum cast product 40, for example, a steel ring 70 made of steel is preliminarily set on the inner surface of the forming die 20. The steel ring has a U-shaped section and is circumferentially set on the inner surface of the forming die 20. When the aluminum cast product 40 is used as a piston for piston internal combustion engine, the steel ring 70 formes a piston-ring groove.

Further, as shown in FIG. 12, the outer surface of the forming die 20 is provided with a plurality of cylindrical vent holes 71. The vent holes 71 serve to let gas generated from the forming die 20 upon casting flow out, and each of the vent holes 71 extends along a radial direction from the outer surface of the forming die 20 toward the center of the forming die 20. Also, the moving die 12 is provided with vent ports 75, which guide the gas from the forming die 20 to the outside corresponding to the vent holes 71.

Some vent holes 71 in the forming die 20 are filled with a metal filling 72 in the bottom thereof, and the metal filling 72 reinforces the forming die 20. Further, some other vent holes 71 are filled with a fusible filling 73 comprised of a low-melting point metal or low-melting point resin, and the fusible filling 73 reinforces the forming die 20. The fusible filling 73 is arranged to melt by heat from the forming die 20 when the forming die is heated upon casting, and then to flow out through the vent ports 75.

Next described is a casting method using the forming die constructed in the above structure. First, as shown in FIG. 11, the forming die 20 is set in the cavity 15 in the moving die, and then the moving die 12 is moved toward the stationary die 11 before the cavity 15 of the moving die 12 is hermetically closed by the stationary die 11 (FIG. 12). In this sate, the metal core 13 projects into the cavity 15 from the stationary die 11. Then, molten aluminum 85 is charged through the guide path 18*a* and the gate 18 into the cavity 15 (FIG. 13). The molten aluminum 85 filled in the cavity 15 is rapidly cooled by the stationary die 11 and moving die 12 to form the aluminum cast product 40. In this case, the outer surface of the aluminum cast product 40 is formed by the inner surface of the forming die 20.

Here, heat transfer occurs also from the molten aluminum 85 to the forming die 20 during the casting. When the forming die 20 is made of powder graphite and the thermosetting synthetic resin, the thermosetting synthetic resin is further cured by heating, whereby the forming die 20 does not melt or soften during casting.

However, the forming die 20 containing the thermosetting synthetic resin generates gas by rapid heating, but the gas generated from the forming die 20 is discharged from the vent holes 71 through the vent ports 75 to the outside. Further, the fusible filling 73 in the vent holes 71 flows outward through the vent ports 71 because of heating of the forming die 20. Then, the gas generated from the forming die 20 also flows outward through the vent holes 71 from which the fusible filling 73 flowed out, and then through the vent ports 75.

As described above, the thermoplastic resin may be used instead of the thermosetting resin. In this case, the forming die 20 is comprised of powder graphite and the thermoplastic synthetic resin. Since the thermal conductivity of the forming die 20 composed of graphite and the thermoplastic synthetic resin is far smaller than that of the steel stationary die 11 and moving die 12, an amount of heat transfer from molten aluminum to the forming die 20 becomes extremely small. Thus, the forming die 20 does not melt or soften during casting. Here, the molding die 20 containing the thermoplastic synthetic resin generates gas, but the gas is discharged from the vent hole 71 through the vent port 75 to the outside. Further, after the fusible filling 73 in the vent holes 71 flows out through the vent ports 71, the generated gas also flows out through the vent ports 75 from the vent holes 71 from which the fusible filling 73 has flowed out.

Next, the moving die **12** is separated from the stationary die **11**, and the aluminum cast product **40** and forming die **20** are taken together out of the cavity **15** formed in the moving die **12**.

In this case, because the forming die **20** has excellent lubricity and releasability because of the graphite component, the forming die **20** can be easily and simply taken together with the aluminum cast product **40** out of the cavity **15**, while preventing a part of the forming die **20** from being deposited on or adhering to the inside of the cavity **15**.

Then, the aluminum cast product **40** and the forming die **20** are subjected to a salt bath treatment in a molten salt **80** stored in a tank **80***a*, as shown in FIG. **15**. This salt bath treatment in the molten salt **80** decomposes the organic material binding powder graphite with each other, such as the thermosetting synthetic resin, the thermoplastic synthetic resin, or the natural adhesive in the forming die **20**.

As the molten salt **80**, an alkaline salt (trade name: DGS, No. 4, No. 5, or No. 10) manufactured by KOLENE Company, U.S.A. is used, for example.

When heated to a predetermined temperature, such an alkaline salt becomes liquefied. The salt bath treatment in the liquid alkaline salt oxidizes the organic material such as the thermosetting synthetic resin, the thermoplastic synthetic resin, or the natural adhesive in the forming die **20** to form carbon dioxide gas and sludge mainly composed of Na_2CO_3. Among them, the carbon dioxide gas is discharged from the molten salt **80**, and the sludge precipitates on the bottom of the tank **80***a*. At the same time, powder graphite in the forming die **20** precipitates on the bottom of the tank **80***a*. The sludge and graphite precipitating on the bottom of the tank **80***a* are removed as the case requires.

Heating conditions and a treating period of the salt bath treatment differ depending on the type of the alkaline salt, and it is preferred that the heating temperature be in the range of from 380° C. to 460° C. and that the treating period be a few ten seconds.

The forming die **20** is removed from the aluminum cast product **40** by the salt bath treatment in the molten salt **80**, and then the aluminum cast product **40** is pulled up from the tank **80***a*. Next, the aluminum cast product **40** is post-treated in diluted nitric acid **81** (1% concentration) stored in a tank **81**a. An oxidized layer is formed on the surface of the aluminum cast product **40** by the salt treatment in the molten salt **80**, but it is removed from the surface of the aluminum cast product **40** by the treatment with diluted nitric acid **81**. At the same time, the surface of the aluminum cast product **40** is neutralized.

Then, the aluminum cast product **40** is washed with high-temperature (about 80° C.) water **82** stored in a tank **82***a*, thereby obtaining the aluminum cast product **40** from which the forming die **20** is completely removed. In this case, the steel ring **70** is left on the outer surface of the aluminum cast product **40** (FIG. **14**).

As described above, according to the present embodiment, the forming die **20** is readily removed from the cast product **40** by casting the aluminum cast product **40** using the forming die **20**, removing the cast product **40** and the forming die **20** from the stationary die **11** and the moving die **12**, and then subjecting the cast product **40** and the forming die **20** to the salt bath treatment in the molten salt **80**. The cast product **40** is then subjected to the oxidation treatment in the diluted nitric acid **81** and thereafter washed in high-temperature water **82**. Accordingly, the cast product **40** having a complicated shape of outer surface can be readily and simply obtained.

According to the present embodiment, the outer surface of the cast product can be readily formed by the forming die upon casting. The forming die is then removed from the cast product, whereby the cast product having a desired shape of outer surface can be readily obtained.

Fourth Embodiment

A fourth embodiment of the present invention is described below referring to the drawings. FIG. **16** to FIG. **18** are drawings to show an embodiment of the present invention.

First, an aluminum diecast casting apparatus is schematically described referring to FIG. **16** and FIG. **17**. As shown in FIG. **16** and FIG. **17**, the aluminum diecast casting apparatus **210** is provided with a stationary die **211** and a moving die **212** arranged as movable relative to the stationary die **211**, and a cavity **217** is formed in the stationary die **211** and moving die **212**. Further, the casting die is composed of the stationary die **211** and moving die **212**.

Namely, as shown in FIG. **16** and FIG. **17**, the stationary die **211** and moving die **212** are in close contact with each other at inclined planes **225**, **225** thereof to form the cavity **217** hermetically sealed in the stationary die **211** and the moving die **212**. The cavity **217** is a portion for forming an aluminum cast product **230** described below.

Further, the stationary die **211** is provided with projecting portions **213**, **215** projecting on the cavity **217** side, and, likewise, the moving die **212** is provided with projecting portions **214**, **216** projecting on the cavity **217** side. Among them, the projecting portions **213**, **214** come into contact with each other at the inclined planes **225**, **225** to constitute a metal core **213**, **214** for forming a hollow portion **235** in the aluminum cast product **230**. In addition, the projecting portions **215**, **216** come into contact with each other at the inclined planes **225**, **225** to constitute metal cores **215**, **216** for forming through holes **231**, **231** in the aluminum cast product **230**.

Further, the inclined planes **225**, **225** of the stationary die **211** and moving die **212** are provided each with mount grooves **225***a*, **225***a* for a casting core **220** described below to be mounted therein. The casting core **220** forms a tube portion **233** projecting from a cast product body **230***a* of the aluminum cast product **230**, and is bent in an L-shape. The casting core **220** has a base end portion **221** located in the inside of the stationary die **211** and moving die **212**, an outer portion **222** located near the outer surfaces of the stationary die **211** and moving die **212**, and an intermediate portion **223** located between the base end portion **221** and the outer portion **222**. Among them, the base end portion **221** of the casting core **220** is mounted in the mount grooves **225***a*, **225***a* formed in the projecting portions **213**, **214** of the stationary die **211** and moving die **212**, and the outer portion **222** is set in mount grooves **225***a*, **225***a* formed on the outer sides of the inclined planes **225**, **225** of the stationary die **211** and moving die **212**. Further, the intermediate portion **223** is in contact with neither of the mount grooves **225***a*, **225***a* in the stationary die **211** and moving die **212** as being kept in a floating state in the cavity **217**, whereby the tube portion **233** of the aluminum cast product **230** is formed around the circumference of the intermediate portion **223**.

Furthermore, a gate **218**, which communicates with the cavity **217**, is formed in the stationary die **211** and, further, the gate **218** communicates with a guide path **218***a* having an input port **219** for molten aluminum.

Next, the casting core **220** will be described in detail. The casting core **220** is comprised of powder graphite and a plastic material bonding the powder graphite with each other, for example, a polycarbonate material. The casting core **220** is produced by injection molding using a graphite-added plastic pellet material. The graphite-added plastic pellet material and the core **220** are produced substantially by the same methods as the production procedures described in the second embodiment (FIG. 7 to FIG. 9).

Namely, as shown in FIG. 8 in the second embodiment, the raw material **125** consisting of polycarbonate pellets and powder graphite is put into the hopper **123** in the extruder **110**. A weight ratio between the polycarbonate pellets and powder graphite in the hopper **123** is in the range of 90:10 to 10:90 corresponding to a weight ratio of a polycarbonate component and a graphite component in a graphite-added plastic pellet material **117** as described below. Next, the raw material **125** in the hopper **123** is sent to the cylinder **126**, and the raw material **125** is pressurized in the cylinder **126** with rotation of the screw **128** and heated by the heater **127**.

When the raw material **125** is heated and compressed in the cylinder **126**, the polycarbonate pellets melt to be mixed with powder graphite and the mixture flows out through the die **111** (FIG. 7) from the head **129** of the extruder **110**.

Since graphite does not chemically react with any synthetic resin under environmental conditions below 1000° C., the polycarbonate and graphite exist independently of each other while keeping respective specific properties in the mixture of polycarbonate and graphite.

Next, as shown in FIG. 7, the polycarbonate and graphite mixed in the extruder **110** is fed in the form of a strand mixture **112** from the die **111** to the pelletizer **116**. In the pelletizer **116** the strand mixture **112** is fed by feed rollers **113**, **114** to the rotary knife **115**, and the mixture is finely broken by the rotary knife **115** to obtain the graphite-added plastic pellet material **117** in diameters of 1 to 2 mm.

This graphite-added plastic pellet material **117** is a mixture of the polycarbonate component and graphite component, and the weight ratio between the polycarbonate component and the graphite component is in the range of 90:10 to 10:90 as described previously. If the polycarbonate component is more than 90:10 of the weight ratio between the polycarbonate component and the graphite component, the releasability from the casting dies **211**, **212** and the releasability from the aluminum cast product **230** become slightly degraded for the casting core **220** obtained by injection molding.

If the graphite component is more than 10:90 of the weight ratio between the polycarbonate component and the graphite component, the toughness becomes degraded for the casting core **220** obtained by injection molding.

Incidentally, the combination of the polycarbonate component with the graphite component in the graphite-added pellets **117** can be determined as follows. If the casting core **220** is formed in a simple structure and a large volume, a combination of the polycarbonate component with the graphite component is selected in the range where the volume % of graphite is relatively large, from Table 1 in the second embodiment. In this case, for example, supposing a combination with the volume % of graphite being 70% is selected, 1540 g of graphite and 360 g of polycarbonate are mixed with each other.

On the other hand, if the casting core **220** is formed in a complex structure and a small volume, a combination of the polycarbonate component with the graphite component is selected in the range where the volume % of graphite is relatively small.

The casting die **220** using the graphite-added plastic pellet material **117** thus obtained is next produced as shown in FIG. **9**.

As shown in FIG. **9**, the injection molding machine **130** has the injection ram **135** arranged as slidable in the injection cylinder **134**, and the oil hydraulic motor **137** driving to rotate the injection ram **135** through the drive shaft **138**. The screw **132** is connected with the injection ram **135**, and the screw **132** is set in the barrel **136**. Further, the graphite-added plastic pellet material **117** is supplied from the hopper **131** to the screw **132**. The nozzle **139** is provided at the distal end of screw **132**, and the nozzle **139** is connected to the injection die composed of the stationary die **140** and the moving die **141**.

Next described is the production method of the casting core **220**. As shown in FIG. **9**, the graphite-added plastic pellet material **117** is first put into the hopper **131**, and then the oil hydraulic motor **137** starts rotating the screw **132** through the injection ram **135**. During this time, the graphite-added plastic pellet material **117** is supplied into the screw **132**, whereby the polycarbonate component in the graphite-added plastic pellet material **117** is melted by the rotation of screw **132**. Then the mixture in which powder graphite is mixed in the melted polycarbonate is injected through the nozzle **139** into the cavity between the stationary die **140** and the moving die **141**, thereby obtaining the casting core **220** made of polycarbonate and powder graphite.

The polycarbonate component among the components of the casting core **220** has characteristics of excellent heat resistance, excellent adhesion under high-temperature environment, and high toughness. On the other hand, powder graphite is a material of the hexagonal system and has the hardness of 1.5 and the relative density of 2.2. The graphite component has excellent heat resistance, and also has excellent lubricity and releasability from the crystal structure thereof. Also, the graphite component has the considerable mechanical strength at high temperatures and has such a characteristic that it is soluble in neither inorganic solvents nor organic solvents.

Further, polycarbonate and graphite do not chemically react with each other as described previously, and can exist with respective specific properties. From these points, the casting core **220**, obtained by kneading to bind powder graphite with polycarbonate, becomes a core for casting excellent in heat resistance and in lubricity. In this case, among the components of the casting core **220**, polycarbonate functions to bond powder graphite to each other.

Next described is an aluminum diecast casting method using the casting core **220** constructed in the above structure.

First, as shown in FIG. **16** and FIG. **17**, the casting core **220** is set in the cavity **217** in the stationary die **211**. In this case, the base end portion **221** of the casting core **220** is set in the mount groove **225***a* formed in the inclined plane **225** of the projecting portion **213** in the stationary die **211**, and the outer portion **222** is set in the mount groove **225***a* formed in the outer side of the inclined plane **225** of the stationary die **211**.

Next, the moving die **212** is moved toward the stationary die **211**, so that the inclined plane **225** of the stationary die **211** and the inclined plane **225** of the moving die **212** come into close contact with each other before the cavity **217** in the stationary die **211** and moving die **212** is hermetically closed. In this case, the intermediate portion **222** of the casting core **220** is in contact with neither one of the mount grooves **225***a* of the stationary die **211** and moving die **212**, in the floating state in the cavity. Further, the base end portion **221** of the casting core **220** is set in the metal core composed of the projecting portions **213**, **214**.

In this state, molten aluminum is put through the input port **219** into the guide path **218***a*, so that molten aluminum is injected from the guide path **218***a* through the gate **218** into the cavity **217**. Molten aluminum flowing from the gate **218** into the cavity **217** is injected in a spray form, and the temperature is about 600° C.

As shown in FIG. 16 and FIG. 17, molten aluminum, flowing from the gate 218 into the cavity 217, then spreads in the cavity 217. In this case, the cavity 217 forms the aluminum cast product 230 composed of the cast product body 230*a* and the tube portion 233 having a flange portion 236. Among them, the tube portion 233 is formed around the circumference of the intermediate portion 222 of the cast core 220. Further, the hollow portion 35 is formed by the metal core 213, 214 of the stationary die 211 and moving die 212, and the through holes 231, 231 are formed by the metal cores 215, 216.

Then, molten aluminum filled in the cavity 217 is rapidly cooled by the stationary die 211 and moving die 212.

In this case, heat transfer occurs also from molten aluminum to the side of casting core 220 made of powder graphite and polycarbonate. However, because the thermal conductivity of the casting core 220 made of powder graphite and polycarbonate is far smaller than that of the steel stationary die 211 and moving die 212, an amount of heat transfer from molten aluminum to the casting core 220 becomes extremely small. Further, because of instantaneous injection casting specific to the diecast casting, the casting core 220 made of powder graphite and polycarbonate does not melt during casting, and the aluminum cast product 230 excellent in accuracy of shape can be formed accordingly.

If the surface of the casting core 220 near thick portions of the aluminum cast product 230 formed by the casting core 220, for example, near the flange portion 236, is coated with a very-high-temperature-resistant silicon rubber not shown, the casting core 220 will not melt even if escape of heat, for example, from the flange portion 236 becomes slow.

Next, the moving die 212 is separated from the stationary die 211, and the aluminum cast product 230 and casting core 220 are taken together out of the cavity 217 formed in the stationary die 211 and moving die 212.

In this case, because the casting core 220 has excellent heat resistance, lubricity, and releasability because of the graphite component, the casting core 220 can be easily and simply taken together with the aluminum cast product 230 out of the cavity 217, while preventing a part of the casting core 220 from being deposited on or adhering to the inside of the cavity 217. Accordingly, the inside of the cavity 217 does not have to be cleaned every aluminum diecasting, whereby the aluminum diecasting can be completely automatized. Next, the aluminum cast product 230 and casting core 220 are heated at about 300° C., whereby the polycarbonate component in the casting core 220 melts and partly flows out.

As shown in FIG. 18, the aluminum product 230 is next immersed together with the casting core 220 in a solvent 241 in a container 240. In FIG. 18, the aluminum cast product 230 is shown without the casting core 220 for convenience' sake. Thus immersing the aluminum casting product 230 and casting core 220 in the solvent 241, the remaining polycarbonate component in the casting core 220 is dissolved in the solvent 241 to be completely removed from the aluminum cast product 230. On the other hand, because the graphite component in the casting core 220 is excellent in lubricity and releasability, it is easily and simply removed from the aluminum cast product 230 to precipitate on the bottom in the solvent 241. Also, the polycarbonate component dissolved in the solvent 241 comes up to the surface of solvent 241.

Because of this, the graphite component precipitating on the bottom of solvent 241 can be easily and simply separated in the solvent from the dissolved polycarbonate component floating on the surface of solvent 241, thus facilitating disposal.

Also, setting a supersonic generator (not shown) in the solvent 241 in the container 240, supersonic waves can be generated in the solvent 241, whereby the casting core 220 can be dissolved and removed more quickly.

The following hydrocarbon solvent is used as the solvent for dissolving to remove the casting core 220.

Methylene chloride (dicohloromethane or methylene chloride), NMP (N-methyl-2-olefin), DMA (NN-dimethylformamide), MEK (methyl ethyl ketone), ethyl acetate (ester).

According to the present embodiment as described, the casting core 220 can be dissolved and removed from the aluminum cast product 230 simply by immersing the aluminum cast product 230 together with the casting core 220 into the solvent 241 after casting of the aluminum cast product 230 using the casting core 220 made of powder graphite and polycarbonate. Thus, the aluminum cast product 230 can be easily and simply obtained as provided with the tube portion 233 projecting from the product body 230*a*.

(Modifications)

Modifications of the present embodiment are next described. The above embodiment showed an example in which the casting core 220 was the one made of powder graphite and polycarbonate, but without a need to be limited to this, polycarbonate may be replaced by another thermoplastic resin. In this case, the thermoplastic inner resin may be selected from fluororesins (polyfluoroethylene resins) such as ethylene tetrafluoride, polyimide resins, polyamide-imide resins polysulfone resins, vinyl chloride resins, polyamide resins (nylon resins), polypropylene resins, polyethylene resins, polyester resins (Tetron resins), or polysulfonic acid resins.

In another modification, the casting core 220 is composed of a plurality of parts, wherein thick and simple portions among the parts are arranged to include a more graphite component but a less plastic component while thin and complex portions are arranged to include a less graphite component and a more plastic component. When the thick and simple portions are arranged to include an increased amount of the graphite component as described, the casting core 220 can be easily removed from the aluminum cast product 230 even with a smaller amount of usage of the solvent.

In the above embodiment the aluminum diecasting method was described as a diecasting method, but the present invention can be applied to any other diecasting method, such as the gravity diecasting method, the low pressure diecasting method, and the precision diecasting method. Further, the cast product may be not only of aluminum, but also of lead, zinc, magnesium, manganese or an alloy thereof.

Further, the method for removing the casting core 220 from the aluminum cast product 230 may be, for example, such a method that the aluminum cast product 230 and casting core 220 are heated in a furnace to bring the plastic component in the casting core 220 into a molten state whereby the plastic component is made to flow together with the graphite component out from the aluminum cast product 230. Also, the casting core 220 can be pulled out of the aluminum cast product 230 as heating the aluminum cast product 230 and casting core 220 by a burner to bring the plastic component in the casting core 220 into a molten state.

As described above, according to the present embodiment, the cast product having a complicated shape can be easily and simply obtained just by, after producing the cast product using the casting core, taking out the cast product and casting core from the casting die and thereafter removing the casting core from the cast product. In this case, because the graphite component in the casting core is excellent in lubricity and releasability, the cast product and the casting core can be easily taken out of the casting die.

Fifth Embodiment

A fifth embodiment of the present invention is described below referring to the drawings. FIG. 19 to FIG. 25 are drawings to show an embodiment of the present invention.

First, an aluminum diecast casting apparatus is schematically described referring to FIG. 19 and FIG. 20. As shown in FIG. 19 and FIG. 20, the aluminum diecast casting apparatus is provided with a stationary die **311** and a moving die **312** arranged as movable relative to the stationary die **311**, and a cavity **315** is formed in the moving die **312**. Also, the stationary die **311** is arranged to hermetically seal the cavity **315** in the moving die **312**.

Further, a gate **318**, which communicates with the cavity **315**, is formed in the stationary die **311** and, a guide path **318*a*** having an input port for molten aluminum communicates with the gate **318**.

The stationary die **311** is provided with a core **320** projecting into the cavity **315** in the moving die **312**, and this core **320** forms a space **343** in an aluminum cast product **340** as detailed later (FIG. 24). Here, the stationary die **311** and moving die **312** all are made of steel.

A forming die **330** for formation of outer surface, which forms an outer surface of the aluminum cast product, is set into the cavity **315** in the moving die **312**. The cavity **315** in the moving die **312** is cylindrical when observed from the side of stationary die **311**, and the forming die **330** is substantially cylindrical in correspondence with the cylindrical shape of the cavity **315**. Likewise, the core **320** is also substantially cylindrical.

Next described is the material for the core **320** and forming die **330**. The core **320** and forming die **330** are comprised of the same material and of powder graphite and an organic material having an adhesive function to bind the powder graphite. The organic material to bind the powder graphite can be a plastic, e.g., a thermosetting synthetic resin such as a phenol resin, a urea resin, a melanin resin, an unsaturated polyester resin, a silicone resin, etc.

The thermosetting synthetic resin is one obtained generally by forming initial, linear polymer molecules and further raising the temperature to form bondings between them (crosslinking). As a result, a three-dimensional (stereoscopic) network is formed to increase the molecular weight, whereby it comes to have such a property that it does not soften when again heated.

Incidentally, a weight ratio between the powder graphite and the thermosetting synthetic resin is in the range of 90:10 to 10:90.

Powder graphite is a material of the hexagonal system and has the hardness of 1.5 and the relative density of 2.2. Graphite has excellent heat resistance and also has excellent lubricity (releasability) from the crystal structure thereof. Also, graphite has the considerable mechanical strength at high temperatures and has such a characteristic that it is soluble in neither inorganic solvents nor organic solvents.

Incidentally, as shown in FIG. 21 and FIG. 22, the core **320** has a large diameter portion **320**a located on the side of stationary die **311**, a small diameter portion **320*b*** located on the side of moving die **312**, and a projecting portion **321**, formed on the large diameter portion **320*a*** for forming a through hole **340*a*** (FIG. 24) in the aluminum cast product **340**. Further, a metal molded article different in quality from the aluminum cast product **340**, for example, a copper molded article **322** is preliminarily buried inside the small diameter portion **320*b*** in the core **320**. When the aluminum cast product **340** is used as a piston, the copper molded article **322** can be used as a radiator plate.

The copper molded article **322** is produced as follows. Namely, as shown in FIG. 23A, leg portions **322*b*** are made to stand up along cut lines **326** from a copper plate **325**, and a distal end of each leg portion **322*b*** is bent. Then, as shown in FIG. 23C the copper plate **325** is bent in such a manner that the leg portions **322*b*** are out, thereby forming the copper molded article **322** composed of the body **322*a*** and the leg portions **322*b***.

The copper molded article **322** is set in a resin forming die (not shown) and then a material for the core **320** is filled into the resin forming die. As shown in FIG. 21 and FIG. 22, the core **320** having the copper molded article **322** preliminarily buried therein is obtained by this procedure. In this case, the body **322*a*** in the copper molded article **322** is completely buried in the core **320**, but the distal ends **323** of the leg portions **322*b*** project out from the core **320**.

Next described is a casting method using the core **320** constructed in the above structure. First, as shown in FIG. 19, the core **320** is set in the stationary die **311**, and the forming die **330** is set in the cavity **315** in the moving die **312**. Then, the moving die **312** comes to fit to the stationary die **311**, so that the cavity **315** in the moving die **312** is hermetically sealed by the stationary die **311**. In this case, the core **320** projects into the cavity **315** in the moving die **312** from the side of stationary die **311**.

Then, molten aluminum **345** is charged through the guide path **318*a*** and the gate **318** into the cavity **315** (FIG. 20). The molten aluminum **345** filled in the cavity **315** is rapidly cooled, thereby forming the aluminum cast product **340** by the casting method. In this case, a shape of the inner surface of the aluminum cast product **340** is formed by a shape of the outer surface of the core **320**, and a shape of the outer surface of the aluminum cast product **340** is formed by a shape of the inner surface of the forming die **330**.

Here, heat transfer also occurs from the molten aluminum **345** to the core **320** and forming die **330** during the casting. The core **320** and the forming die **330** both are made of powder graphite and the thermosetting synthetic resin, and the thermosetting synthetic resin is further cured by the heat. Therefore, the core **320** and die **330** do not melt or soften during casting.

Next, the moving die **312** is separated from the stationary die **311**, and the aluminum cast product **340** is taken together with the core **320** and forming die **330** out of the cavity **315** in the moving die **312**.

In this case, since the core **320** and forming die **330** have excellent lubricity and releasability because of the graphite component, the core **320** and forming die **330** can be easily and simply taken together with the aluminum cast product **340** out of the stationary die **311** and moving die **312**, while preventing a part of the core **320** or forming die **330** from being deposited on or adhering to the stationary die **311** or moving die **312**.

Then, as shown in FIG. 25, the aluminum cast product **340**, core **320** and forming die **330** are subjected to a salt bath treatment in a molten salt **380** stored in a tank **380*a***. This salt bath treatment in the molten salt **380** decomposes the organic material comprised of the thermosetting synthetic resin in the core **320** and forming die **330**.

As the molten salt **380**, an alkaline salt (trade name: DGS, No. 4, No. 5 or No. 10) manufactured by KOLENE Company, U.S.A. is used, for example.

Such an alkaline salt becomes liquefied when heated to a predetermined temperature. The salt bath treatment in the liquid alkaline salt oxidizes the organic material comprised of the thermosetting synthetic resin in the core **320** and forming die **330** to form carbon dioxide gas and sludge mainly composed of Na_2CO_3. Among them, the carbon dioxide gas is discharged from the molten salt **380**, and the sludge precipitates on the bottom of the tank **380***a*. At the same time, powder graphite in the core **320** and forming die **330** precipitates on the bottom of the tank **380***a*.

The sludge and graphite, precipitating on the bottom of the tank **380***a*, are removed as occasion demands.

Heating conditions and a treating period of the salt bath treatment differ depending on the type of the alkaline salt, and it is preferred that the heating temperature be in the range of from 380° C. to 460° C. and that the treating period be a few ten seconds.

The core **320** and forming die **330** are removed from the aluminum cast product **340** by the salt bath treatment in the molten salt **380**, and then the aluminum cast product **340** is pulled up from the tank **380***a*. Next, the aluminum cast product **340** is post-treated in diluted nitric acid **381** (1% concentration) stored in a tank **381***a*. An oxidized layer is formed on the surface of the aluminum cast product **340** by the salt bath treatment in the molten salt **380**, but it is removed from the surface of the aluminum cast product **340** by the treatment in diluted nitric acid **381**. At the same time, the surface of the aluminum cast product **340** is neutralized.

Then, the aluminum cast product **340** is washed with high-temperature (about 80° C.) water **382** stored in a tank **382***a*, thereby obtaining the aluminum cast product (piston) **340** from which the core **320** and forming die **330** are completely removed. In this case, the through hole **340***a* is formed in the aluminum cast product **340** by the projecting portion **321**, and the metal molded article **322** composed of the body **322***a* and the leg portion **322**b is formed in the space **343** in the aluminum cast product **340** (FIG. 22). This metal molded article **340** functions as a radiation plate c the piston **340**.

As described above, according to the present embodiment, the core **320** and forming die **330** can be readily removed from the cast product **340**, by after casting the aluminum cast product **340** using the core **320** and form die **330**, taking the cast product **340**, core **320**, and forming die **330** from the stationary die **311** and the moving die **312**, and then subjecting the cast product **340**, core **320**, and forming die **330** to the salt bath treatment in the molten salt **380**. The cast product **340** is then subjected to the oxidation treatment in the diluted nitric acid **381** and thereafter is washed in high-temperature water **382**. Accordingly, the cast product **340** having complicated shapes of inner and outer surfaces can be readily and simply obtained.

The above embodiment showed a case in which the forming die **330** was set in the cavity **315** in the moving die **312**, but forming die **330** is not necessarily set therein. If the forming die **330** is not set, the core **320** may be comprised of powder graphite and an organic material for binding the powder graphite with each other, and, for example, a thermoplastic synthetic resin such as polycarbonate, or a natural adhesive such as starch, paste, etc. may be used as the organic material. In this case, heat of the molten aluminum **345** filled in the cavity **315** during casting transfers to the side of moving die **312** with large thermal conductivity, so that the core **320** does not soften or melt.

Then, the aluminum cast product **340** and core **320** are subjected to the salt bath treatment in the molten salt **380**. In this case, the thermoplastic synthetic resin or natural adhesive contained in the core **320** is oxidized to be decomposed into carbon dioxide gas and sludge mainly containing Na_2CO_3.

Incidentally, if the forming die **330** is not set in the cavity **315** in the moving die **312**, a metal buried portion **350** made of steel may be buried in a portion of the core **320** corresponding to a thick portion of the cast product **340** in order to prevent shrinkage of the cast product **340** (FIG. **19**). The metal buried portion **350** is exposed to outside the core **320**, and thermal conductivities are made even between the metal buried portion **350** located inside the cast product **340** and the moving die (made of steel) **312** located outside the cast product **340**, whereby shrinkage of the cast product **340** can be prevented.

In addition, after being taken from the stationary die **311** and the moving die, the cast product **340**, the core **320** and the forming die **330** may be heated in a furnace **400** (FIG. **24**) so as to. flow the organic materials in the forming die **330** and the core **320**. As a result, the forming die **330** and the core **320** are removed from the cast product **340**. The cast product **340** is then subjected to the salt bath treatment in the molten salt **380** to decompose the rests of the organic materials of the forming die **330** and the core **320**. Next, the cast product **340** is subjected to the oxidation treatment in the diluted nitric acid **381** and thereafter is washed in the high-temperature water **382**.

In this case, instead of being subjected to the salt bath treatment, the cast product **340** can be heat-treated in a fluidized layer **385** comprising alumina fine particles (or sand fine particles) to decompose the rests of the organic materials of the forming die **330** and the core **320** (FIG. **39B**).

Otherwise, the cast product **340** can be immersed in a solvent to dissolve the rests of the organic materials of the forming die **330** and the core **320**.

The solvent for dissolving to remove the organic materials is one selected from the following hydrocarbon solvents.

Methylene chloride (dichloromethane or methylene chloride), NMP (N-methyl-2-olefin), DMP (NN-dimethylformamide), MFK (methyl ethyl ketone), ethyl acetate (ester).

In the case of setting either of the forming die **330** and the core **320** in the cavity **315**, after being heated in the furnace **400**, the cast product **340** and either of them are subjected to the salt bath treatment, heat-treated in a fluidized layer **381** or immerse in the solvent to remove the rests of the organic materials of the forming die **330** and the core **320**.

According to the present embodiment, the inner surface of the cast product can be readily formed by the core upon casting. The core is then removed from the cast product, whereby the cast product having a desired shape of inner surface can be readily obtained. Also, the inner surface and outer surface of the cast product can be readily formed by the core and forming die upon casting. The core and forming die are then removed from the cast product, whereby the cast product having desired shapes of inner and outer surfaces can be readily obtained.

Sixth Embodiment

A sixth embodiment of the present invention is described below referring to the drawings. FIG. **26** to FIG. **40B** are drawings to show embodiments of a core, a casting method using the core, and a hollow piston according to the present invention.

First, an aluminum diecast casting apparatus is schematically described referring to FIG. **26** to FIG. **32**, and FIG. **35**. As shown in FIG. **29**, FIG. **30**A, and FIG. **30B**, the aluminum diecast casting apparatus is provided with a stationary die **311** having a mount projection **311***a* and a moving die **312** arranged as movable relative to the stationary die **311**. The moving die **312** is composed of an outer frame **312***c* and split dies **312***a*, **312***b* arranged as movable in the outer frame **312***c*. As shown in FIG. **35**, the outer frame **312***c* is arranged to move along guides **313** away from or toward the stationary die **311**. Also, the split dies **312***a*, **312***b* are arranged to leave or approach each other in directions perpendicular to the guides **313**. A cavity **315** is formed between the split dies **312***a*, **312***b*, and the stationary die **311** is arranged to hermetically seal the cavity **315** in the split dies **312***a*, **312***b*.

Further, as shown in FIGS. **30**A and **30**B, a gate **318**, which communicates with the cavity **315**, is formed in the outer frame **312***c* and, further, a guide path **318***a* having an input port for molten aluminum, which communicates with the gate **318**, is formed in the stationary die **311**. The guide path **318***a* is further provided with an extrusion piston **319** for extruding molten aluminum into the cavity **315**. Here, FIG. **30**A shows a state in which molten aluminum **345** is injected into the cavity **315**, and FIG. **30B** is a sectional view along the B-line.

Furthermore, as shown in FIG. **29**, FIG. **30**A, and FIG. **30B**, a core **320** projecting into the cavity **315** in the moving die **312** is set in fit on the mount projection **311***a* of the stationary die **311**, and the core **320** forms a space **343** in the aluminum cast product **340** (FIG. **34**) described below. The stationary die **311** having the mount projection **311***a*, and the moving die **312** composed of the split dies **312***a*, **312***b* and the outer frame **312***c*, all are made of steel.

The cavity **315** in the moving die **312** is cylindrical when observed from the side of stationary die **311**, and the core **320** is substantially cylindrical in correspondence with the cylindrical shape of the cavity **315**.

Next described is a material for the core **320**. The core **320** is comprised of powder graphite and an organic material having an adhesive function to bind the powder graphite. The organic material to bind the powder graphite can be a thermosetting synthetic resin such as a phenol resin, a urea resin, a melamine resin, an unsaturated polyester resin, a silicone resin, etc.

The thermosetting synthetic resin is one obtained generally by forming initial, linear polymer molecules and further raising the temperature to form bondings between them (crosslinking). As a result, a three-dimensional (stereoscopic) network is formed to increase the molecular weight, whereby it comes to have such a property that it does not soften when again heated.

A weight ratio between powder graphite and the thermosetting synthetic resin is in the range of 90:10 to 10:90 in this embodiment.

Further, powder graphite is a material of the hexagonal system and has the hardness of 1.5 and the relative density of 2.2. Graphite has excellent heat resistance and also has excellent lubricity (releasability) from the crystal structure thereof. Also, graphite has the considerable mechanical strength at high temperatures and has such a characteristic that it is soluble in neither inorganic solvents nor organic solvents.

Incidentally, as shown in FIG. **37** and FIG. **38**, the core **320** has a large diameter portion **320***a* located on the side of stationary die **311**, a small diameter portion **320***b* located on the side of moving die **312**, and a projecting portion **321**, formed on the large diameter portion **320***a*, for forming a through hole **340a** in the aluminum cast product **340** (FIG. **34**). Further, a hollow portion **325** is formed inside the core **320**, as opening one side **325***a*. The core **320** is mounted onto the mount projection **311***a* of the stationary die **311** from the side of the opening one side **325***a*.

Further, a metal molded article different in quality from the aluminum cast product **340**, for example, a copper

molded article **322**, is preliminarily buried inside the core **320**. When the aluminum cast product **340** is used as a hollow piston for an internal combustion engine, the copper molded article **322** can be used as a radiator apparatus. This copper molded article **322** is composed of a body **322***a* set along the inner surface of hollow portion **325** in the core **320**, leg portions **322***b* extending outwardly from the body **322***a*, and a copper circular plate **324** connected to distal ends **323** of the leg portions **322***b* above the core **320**, as shown in FIG. **37** and FIG. **38**.

The copper molded article **322** is produced as follows. Namely, as shown in FIGS. **36**A and **3322** the leg portions **322***b* are made to stand up along cut lines **326** from a copper plate **325**, and then, the distal end **323** of each leg portion **322***b* is bent. Then, as shown in FIG. **36**C, the copper plate **325** is bent in such a manner that the leg portions **322***b* are out, and the copper circular plate **324** is connected to the distal end **323** of each leg portion **322***b*. The copper molded article **322** composed of the body **322***a* , leg portions **322***b*, and copper circular plate **324** is produced in this manner.

Next, a solder coating layer is formed over the entire surface of the copper molded article **322**. The solder coating layer has a function to melt during casing to enhance bonding strength between the aluminum cast product **340** and the copper molded article **322**. Therefore, the solder coating layer may be arranged not to be formed over the entire surface of the copper molded article **322**, but to be formed on parts of the copper molded article **322** being in contact with the aluminum casting product **340**.

The copper molded article **322** is set in a resin molding die (not shown), and then a material for the core **320** is filled into the resin forming die. As shown in FIG. **37** and FIG. **38**, the core **320** in which the copper molded article **322** is preliminarily buried therein is obtained by this procedure. In this case, the body **322***a* of the copper molded article **322** is arranged along the inner surface of the hollow portion **325** in the core **320** and the leg portions **322***b* extend outwardly from the body **322***a* with the distal ends **323** thereof projecting out from the core **320**. Further, the copper circular plate **324** is connected to the distal ends **323** of the leg portions **322***b* above the core **320**.

Next described is a casting method using the core **320** constructed in the above structure. First prepared, as shown in FIG. **26**, are the stationary die **311** having the mount projection **311***a*, and the moving die **312** provided with a pair of split dies **312***a*, **312***b* inside the outer frame **312***c*. Then, as shown in FIG. **27**, the core **320** is set on the mount projection **311***a* of the stationary die **311**. The outer frame **312***c* in the moving die **312** moves toward the stationary die **311** along the guide **313** (FIG. **35**), and then the split dies **312***a*, **312***b* in the moving die **312** comes into contact with the stationary die **311**.

In this case, as shown in FIG. **28**, the core **320** projects from the side of stationary die **311** between the split dies **312***a*, **312***b* in the moving die **312**. In FIG. **28**, the split dies **312***a*, **312***b* in the moving die **312** are retracted to positions where they are separate from each other in the outer frame **312***c*. Then, as shown in FIG. **29**, the split dies **312***a*, **312***b* approaches each other in the outer frame **312***c*, so that the split dies **312***a*, **312***b* come into close contact with each other to form the cavity **315** between the split dies **312***a*, **312***b*. At the same timer the cavity **315** is hermetically sealed by the stationary die **311**.

Next, as shown in FIGS. **30**A and **30**B, the extrusion piston **319** is driven to charge molten aluminum **345** into the cavity **315** through the guide path **318***a* and the gate **318**. The molten aluminum **345** filled in the cavity **315** is rapidly cooled by the split dies **312**a, **312**b in the moving die **312**, whereby the aluminum cast product **340** is formed by this casting method. Here, heat transfer occurs also from the molten aluminum **345** to the core **320**. Since the thermal conductivity of the core **320** comprised of powder graphite and the thermosetting resin is smaller than that of the steel moving die **312**, the heat transfer to the core **320** is smaller than that to the moving die **312**.

Furthermore, since the core **320** is comprised of powder graphite and the thermosetting resin cured by heat, it becomes further cured by heat when the thermosetting resin is heated. Therefore, the core **320** does not soften or melt upon casting.

As shown in FIG. **31**, the outer frame **312**c in the moving die **312** is next moved along the guides **313** (FIG. **35**), whereby the moving die **312** is separated from the stationary die **311**. In this case, because the core **320** has excellent lubricity and releasability because of the graphite component, the core **320** can be easily and simply removed from the mount projection **311**a of the stationary die **311** Then, as shown in FIG. **32**, the split dies **312**a, **312**b in the moving die **312** are separated from each other, and aluminum cast product **340** is removed together with the **320** from the cavity **315** formed in the moving die **312**.

The aluminum cast product **340** in which the core **320** is incorporated is obtained in this manner. The aluminum cast product **340** is used as a hollow piston for internal combustion engine, which is composed of a top wall **341** in which the copper circular plate **324** is buried, and a side wall **342** opening one side and having the space **343**.

Then, the aluminum cast product **340** and core **320** are subjected to a salt bath treatment in a molten salt **380** stored in a tank **380**a, as shown in FIG. **39**A. This salt bath treatment in the molten salt **380** decomposes the organic material comprised of the thermosetting resin in the core **320**.

As the molten salt **380**, an alkaline salt (trade name: DGS, No. 4, No. 5, or No. 10) manufactured by KOLENE Company, U.S.A. is used, for example.

When heated to a predetermined temperature, such an alkaline salt becomes liquefied. The salt bath treatment in the liquid alkaline salt oxidizes the organic material comprised of the thermosetting resin in the core **320** to decompose it into carbon dioxide gas and sludge mainly composed of Na_2CO_3. Among them, the carbon dioxide gas is discharged out from the molten salt **380**, and the sludge precipitates on the bottom of the tank **380**a. At the same time, powder graphite in the core **320** precipitates on the bottom of the tank **380**a.

The sludge and graphite, precipitating on the bottom of the tank **380**a, are removed as occasion demands.

Heating conditions and a treating period of the salt bath treatment differ depending on the type of the alkaline salt, and it is preferred that the heating temperature be in the range of from 380° C. to 460° C. and that the treating period be a few ten seconds.

The core **320** is removed from the aluminum cast product **340** by the salt bath treatment in the molten salt **380**, and then the aluminum cast product **340** is pulled up from the tank **380**a. Next, the aluminum cast product **340** is post-treated in diluted nitric acid **381** (1% concentration) stored in a tank **381**a. An oxidized later is formed on the surface of the aluminum cast product **340** by the salt bath treatment in the molten salt **380**, but it is removed from the surface of the aluminum cast product **340** by the treatment in diluted nitric acid **381**. At the same time, the surface of the aluminum cast product **340** is neutralized.

Then, the aluminum cast product **340** is washed with high-temperature (about 80° C.) water **382** stored in a tank **382**a, thereby obtaining the aluminum cast product (a hollow piston for internal combustion engine) **340** from which the core **320** is completely removed. In FIG. **34**, the through hole **340**a is formed in the aluminum cast product **340** by the projecting portion **321** in the core **320**, and the aluminum cast product **340** is provided with the copper molded article **322**.

In this case, the cast product **340** is composed, as shown in FIG. **34**, of the top wall **341** and the side wall **342** inside of which the space **343** is formed, and one side of the space is open. The copper circular plate **324** of the copper molded article **322** is buried in the top wall **341**, and the copper circular plate **324** is connected to the body **322**a through the leg portions **322**b . This body **322**a is disposed inside the space **343**.

When the cast product **340** is used as a hollow piston for internal combustion engine, the top wall **341** becomes a portion directly heated in a combustion chamber, and heat of the top wall **341** is transferred to the body **322**a from the copper circular plate **324** through the leg portions **322**b . Then the heat in the body **322**a is discharged into the space **343**.

The cast product **340** as a hollow piston may be produced not only by the aluminum diecast casting method, but also by the gravity casting method.

FIG. **39**A showed an example in which the thermosetting resin in the core **320** was decomposed by the salt bath treatment, but the cast product **340** and core **320** may be heat-treated in a fluidized layer **385** comprising alumina fine particles (or sand fine particles), as shown in FIG. **39**B. Namely, in FIG. **39**B, a tank **388** forming the fluidized layer **385** is provided in a casing **383** and a heater **387** is provided outside the tank **388**.

Alumina fine particles (or sand fine particles) are stored in the tank **388**, and the fluidized layer **385** composed of the alumina fine particles (or sand fine particles) is formed inside the tank **388** by blowing a gas into the tank **388** through a nozzle **386** from the lower part of the tank **388**. The fluidized layer **385** is heated by the heater **387** up to 800° C. to 900° C., and the cast product **340** and core **320** are put into the fluidized layer **385** thus heated, whereby the thermosetting resin in the core **320** can be decomposed into gas.

Next described are modifications of the material for the core **320**.

The embodiment described above showed an example in which the core **320** was comprised of powder graphite and the thermosetting resin, but the core **320** may be comprised of a heat-resistant inorganic material of powder graphite and an organic material for bonding powder graphite. The organic material may be, for example, a thermoplastic synthetic resin such as polycarbonate, a natural adhesive such as starch, paste, etc., or a synthetic adhesive (for example, Cemedine). Further, a rubber may be used as the organic material.

Further, instead of the heat-resistant inorganic material of powder graphite, another heat-resistant inorganic material such as powder silicon, powder ceramic, powder glass or powder talc may be used.

Furthermore, the entire core **320** may be comprised of the thermosetting resin or the thermoplastic resin.

Whatever material as described above is used for the core **320**, the thermal conductivity of the core **320** is far smaller than the thermal conductivity of the moving die **312** made of steel, whereby the heat of the molten aluminum **345** transfers to the side of moving die **312** during casting. Therefore, heat transfer to the side of core **320** with smaller thermal conductivity becomes small, and thus, the core **320** does not soften or melt.

Whatever material as described above is used for the core **320**, the aluminum cast product **340** and core **320** are treated in the molten salt **380** or in the fluidized layer **385** composed of the alumina particles (or sand particles), to decompose the organic material in the core **320**, and then the core **320** can be removed from the aluminum cast product **340**.

As described above, according to the present embodiment, the core **320** can be removed from the cast product simply by, after casting the aluminum cast product **340** using the core **320**, taking out the cast product **340** and core **320** out of the stationary die **311** and moving die **312** and thereafter subjecting the cast product **340** and core **320** to the salt bath treatment in the molten salt **380** or to the heat treatment in the fluidized layer **385**. The cast product **340** having complicated shapes of inner surface and outer surface can be easily and simply produced accordingly.

(Modifications)

A modification of the present invention is described below referring to FIGS. **40**A, **40**B. As shown in FIGS. **40**A and **40**B, the core **320** is set between a stationary die **311** and a moving die **312**. The core **320** is comprised of powder graphite and a thermosetting resin for binding the powder graphite.

Further, a copper plating **389** is formed on the surface of core **320** and a solder coating layer **390** is further formed on the surface of copper plating **389**.

An aluminum cast product **340**, for example, for piping, is obtained by setting the core **320** between the stationary die **311** and the moving die **312** and then injecting molten aluminum between the stationary die and the moving die **312**. Then, the aluminum cast product **340** incorporated with the core **320** is subjected to a treatment in the molten salt **380** or fluidized layer **385** as described above to decompose the thermosetting resin in the core **320**, and then the core **320** is removed from the aluminum cast product **340**.

The aluminum cast product **340**, for example, for piping, provided with the copper plating **389** inside, is obtained in this manner. In this case, the solder coating layer **390** functions to enhance bonding strength between the aluminum cast product **340** and the copper plating **389**.

Further, the material for core **320** may be the same material as in the embodiment shown in FIG. **26** to FIG. **39**B.

Next described is another modification of the present invention referring to FIG. **41**A to FIG. **44**. First, the core **320** is described referring to FIGS. **41**A, **41**B. FIG. **41**A is a sectional view of the core and FIG. **41**B is a sectional view of the surface of core. As shown in FIG. **41**A, the core **320** has a center member **391** made of blowing styrol, and a core body **392** made of powder graphite bound with a thermosetting resin and formed outside the center member **391**.

The core body **392** of the core **320** is further composed of a thick portion **392***a* being relatively thick and a thin portion **392** being thinner than the thick portion **392**, which extends outwardly from the thick portion **392***a*. Among them, the thick portion **392***a* is a portion for forming a space **343***a* having a relatively large diameter in the cast product **340**, and the thin portion **392***b* is a portion for forming a space **343***b* having a relatively small diameter in a branch tube **344** (FIG. **44**).

A weight ratio of powder graphite to the thermosetting resin in the thick portion **392***a* is higher than that of powder graphite to the thermosetting resin in the thin portion **392***b*. Since the thick portion **392***a* is a portion requiring lubricity and releasability, the weight ratio of powder graphite is set low. On the other hand, because the thin portion **392***b* is a portion requiring strength and toughness, the weight ratio of the thermosetting resin is set high.

Further, as shown in FIG. **41**B, a copper plating **389** is formed on the surface of core body **392**, and a solder coating layer **390** is further formed on the surface of copper plate **389**.

The core **320** having the above structure is then set in the casting die **395**, so that a cavity **315** is formed between the inner surface of the casting die **395** and the outer surface of the core **320** (FIG. **42**).

As shown in FIGS. **43**A and **43**B, molten aluminum is then injected into the cavity **315** in the casting die **395**, and the molten aluminum is cooled by the casting die **395** to form the cast product **340**. Here, FIG. **43**A is a sectional view of the cast product **340** and core **320**, and FIG. **43**B is a sectional view of the surface of core **320**. During casting, heat from the molten aluminum is transferred to the side of core **320**; but, because the thermal conductivity of the core comprised of powder graphite and the thermosetting resin is far smaller than that of the casting die **395**, heat transfer to the core **320** is extremely small.

Furthermore, although a gas is possibly generated from the thermosetting resin in the core **320** by heat from molten aluminum during casting, the gas from the core **320** is interrupted by the copper plating **389**, whereby the gas does not flow out, but flows to the inside. Therefore, no porosity is formed in the cast product **340** by the gas from the core **320**.

Next, the aluminum cast product **340** incorporated with the core **320** is treated in the molten aluminum **380** or fluidized layer **385** as described above, whereby the thermosetting resin in the core **320** decomposes, and then the core **320** is removed from the aluminum cast product **340**.

The aluminum cast product **340** coated with the copper plating **389** inside as shown in FIG. **44** is obtained in this manner. In this case, the solder coating layer **390** functions to enhance bonding strength between the aluminum cast product **340** and the copper plating **389**.

Further, the material for the core **320** may be the same as the one in the embodiment shown in FIG. **26** to FIG. **39**B.

According to the present invention, the inner surface of cast product can be easily formed by the core upon casting. The core is then removed from the cast product, whereby the cast product having a desired shape of inner surface can be readily and simply obtained.

What is claimed is:

1. A casting method using a forming die for formation of an outer surface of a cast product, comprising the steps of:

providing the forming die having inner side surfaces and outer mount surfaces, the die being made of a plastic material;

setting the forming die, for formation of the outer surface of the cast product, on an inner surface of a cavity of a casting die;

pouring a molten metal into the cavity of the casting die to form the cast product including projecting portions communicating between the inner side surfaces and the outer mount surfaces of the forming die; and

taking the cast product and the forming die out of the casting die.

2. A casting method according to claim **1**, wherein

the forming die has a plastic material, and the method further comprises a step of heating the cast product and forming die to make the forming die semi-melted so as to remove the forming die from the cast product.

3. A casting method according to claim 1, wherein the forming die has a plastic material, and the method further comprises a step of immersing the cast product and forming die in a solvent to dissolve the forming die so as to remove the forming die from the cast product.

4. A casting method according to claim 1, wherein the forming die has a plastic material, and the method further comprises a step of subjecting the cast product and forming die to a shot blast treatment so as to remove the forming die from the cast product.

5. A casting method according to claim 1, wherein the forming die has a plastic material, and the method further comprises a step of spraying high-temperature and high-pressure steam onto the cast product and forming die so as to remove the forming die from the cast product.

6. A casting method according to claim 1, wherein the forming die has a rubber material, and the method further comprises a step of heating the cast product and the forming die to make the forming die semi-molten so as to remove the forming die from the cast product.

7. A casting method according to claim 1, wherein the forming die has a rubber material, the method further comprises a step of immersing the cast product and the forming die in a solvent to dissolve the forming die so as to remove the forming die from the cast product.

8. A casting method according to claim 1, wherein the forming die has a rubber material, the method further comprises a step of subjecting the cast product and the forming die to a shot blast treatment so as to remove the forming die from the cast product.

9. A casting method according to claim 1, wherein the forming die has a rubber material, the method further comprises a step of spraying high-temperature and high-pressure steam onto the cast product and the forming die so as to remove the forming die from the cast product.

10. A casting method according to claim 1, wherein the forming die is made of paper, the method further comprises a step of heating the cast product and forming die to burn the forming die so as to remove the forming die thereby.

11. A casting method according to claim 1, wherein the forming die has a plastic material and powder graphite, and the method further comprises a step of heating the cast product and forming die to make the forming die semi-melted so as to remove the forming die from the cast product.

12. A casting method according to claim 1, wherein the forming die has a plastic material and powder graphite, and the method further comprises a step of immersing the cast product and forming die in a solvent to dissolve the forming die so as to remove the forming die from the cast product.

13. A casting method according to claim 1, wherein the forming die has a rubber material and powder graphite, and the method further comprises a step of heating the cast product and the forming die to make the forming die semi-molten so as to remove the forming die from the cast product.

14. A casting method according to claim 1, wherein the forming die has a rubber material and powder graphite, and the method further comprises a step of immersing the cast product and the forming die in a solvent to dissolve the forming die so as to remove the forming die from the cast product.

15. A casting method using a forming die for formation of an outer surface of a cast product, comprising:

providing the forming die having inner side surfaces and outer mount surfaces;

setting the forming die, for formation of the outer surface, containing an organic material, on an inner surface of a cavity of a casting die;

pouring a molten metal into the cavity of the casting die to form cast product including projecting portions communicating between the inner side surfaces and the outer mount surfaces of the forming die;

taking the cast product and the forming die out of the casting die; and

subjecting the cast product and the forming die to a salt bath treatment in a molten salt to decompose the organic material in the forming die into sludge of inorganic material, and gas.

16. A casting method according to claim 15, wherein further comprises a step of neutralizing the cast product in an acid solution after the salt bath treatment, and a step of washing the cast product in water at a high temperature.

17. A casting method using a casting core and a forming die for formation of an outer surface of a cast product, comprising the steps of:

providing the forming die having inner side surfaces and outer mount surfaces;

setting the forming die, for formation of the outer surface, containing an organic material and the core containing an organic material, in a cavity of a casting die;

pouring a molten metal into the cavity of the casting die to form the cast product including projecting portions communicating between the inner side surfaces and the outer mount surfaces of the forming die;

taking the cast product, the forming die, and the core out of the casting die; and

subjecting the cast product, the forming die, and the core to a salt bath treatment in a molten salt to decompose the organic materials in the forming die and the core into sludge of inorganic materials, and gas.

18. A casting method according to claim 17, wherein the method further comprises a step of neutralizing the cast product in an acid solution after the salt bath treatment, and a step of washing the cast product in water at a high temperature.

19. A casting method using a forming die for formation of an outer surface of a cast product, comprising:

providing the forming die having inner side surfaces and outer mount surfaces;

setting the forming die, for formation of the outer surface, containing an organic material, on an inner surface of a cavity of a casting die;

pouring a molten metal into the cavity of the casting die to form the cast product including projecting portions communicating between the inner side surfaces and the outer mount surfaces of the forming die;

taking the cast product and the forming die out of the casting die;

heating the cast product and the forming die so as to flow the organic material in the forming die; and

subjecting the cast product to a salt bath treatment in a molten salt to decompose the rest of the organic material of the foreign die into sludge of inorganic materials, and gas.

20. A casting method using a forming die for formation of an outer surface of a cast product, comprising:

providing the forming die having inner side surfaces and outer mount surfaces;

setting the foreign die, for formation of the outer surface, containing an organic material, on an inner surface of a cavity of a casting die;

pouring a molten metal into the cavity of the casting die to form the cast product including projecting portions communicating between the inner side surfaces and the outer mount surfaces of the forming die;

taking the cast product and the forming die out of the casting die;

heating the cast product and the forming die so as to flow the organic material in the forming die; and

immersing the cast product in a solvent to dissolve the rest of the organic material of the forming die.

21. A casting method using a forming die for formation of an outer surface of a cast product, comprising:

providing the forming die having inner side surfaces and outer mount surfaces;

setting the forming die, for formation of the outer surface, containing an organic material, on an inner surface of a cavity of a casting die;

pouring a molten metal into the cavity of the casting die to form the cast product including projecting portions communicating between the inner side surfaces and the outer mount surfaces of the forming die;

taking the cast product and the forming die out of the casting die;

heating the cast product and the forming die so as to flow the organic material in the forming die; and

subjecting the cast product to a heat treatment in a fluidized layer composed of alumina fine particles or sand fine particles heated to a high temperature, to decompose the rest of the organic material of the forming die into gas.

22. A casting method using a casting core and a forming die for formation of an outer surface of a cast product, comprising:

providing the forming die having inner side surfaces and outer mount surfaces;

setting the forming die, for formation of the outer surface, containing an organic material and the casting core containing an organic material, in a cavity of a casting die;

pouring a molten metal into the cavity of the casting die to form the cast product including projecting portions communicating between the inner side surfaces and the outer mount surfaces of the forming die;

taking the cast product, the forming die and the casting core out of the casting die;

heating the cast product, the forming die and the casting core so as to flow the organic materials in the forming die and the core; and

subjecting the cast product to a salt bath treatment in a molten salt to decompose the rest of the organic materials of the forming die and the core into sludge of inorganic materials, and gas.

23. A casting method using a casting core and a forming die for formation of an outer surface of a cast product, comprising:

providing the forming die having inner side surfaces and outer mount surfaces:

setting the forming die, for formation of the outer surface, containing an organic material, and the casting core containing an organic material in a cavity of a casting die;

pouring a molten metal into the cavity of the casting die to form the cast product including projecting portions communicating between the inner side surfaces and the outer mount surfaces of the forming die;

taking the cast product, the forming die and the casting core out of the casting die;

heating the cast product, the forming die and the casting core so as to flow the organic materials in the forming die and the core; and

immersing the cast product in a solvent to dissolve the rest of the organic materials of the forming die and the core.

24. A casting method using a forming die for formation of an outer surface of a cast product, comprising:

providing the forming die having inner side surfaces and outer mount surfaces;

setting the forming die, for formation of the outer surface, containing an organic material and a casting core containing an organic material, in a cavity of a casting die;

pouring a molten metal into the cavity of the casting die to form the cast product including projecting portions communicating between the inner side surfaces and the outer mount surfaces of the forming die;

taking the cast product, the forming die and the casting core out of the casting die;

heating the cast product, the forming die and the casting core so as to flow the organic materials in the forming die and the core; and

subjecting the cast product to a heat treatment in a fluidized layer composed of alumina fine particles or sand fine particles heated to a high temperature, to decompose the rest of the organic materials of the forming die and the core into gas.

* * * * *